U. S. DEPARTMENT OF AGRICULTURE.

REPORT

OF THE

CHIEF OF THE DIVISION OF FORESTRY

FOR

1890.

BY

B. E. FERNOW.

FROM THE REPORT OF THE SECRETARY OF AGRICULTURE FOR 1890.

WASHINGTON:
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REPORT OF THE CHIEF OF THE DIVISION OF FORESTRY.

SIR: I have the honor to submit my fifth annual report upon the work of the Forestry Division.

With a new fiscal year increased appropriations have marked a new era for this Division, placing at its disposal for the first time funds sufficient to provide for following up in good earnest some special investigations. These funds became available, however, only a few months previous to the writing of this report, and since the arrangements for work were delayed for various reasons proposed methods and promises of results must as yet be discussed rather than the results themselves.

In the line of giving information in answer to requests by letter, the work of the Division has steadily grown. It is to be regretted that the information furnished on many topics is imperfect indeed, no means for acquiring it having hitherto been afforded, especially in the case of requests for statistics regarding timber supplies. The character of much of the correspondence of the Division is indicated by the following classified list of subjects of recent letters:

Statistics.—The loss of useful forest material by fire; present and future supply of white oak; lumber importations and duties; increase or decrease of forest area; soil, timber, and rivers of the Sioux Reservation; manufacture of short-leaved pine in Virginia and North Carolina; amount of long-leaved pine in Georgia and Florida; timber area in the United States and possibilities of exhaustion; area of standing hemlock in the United States and Canada; hard-wood products, markets, etc.; lumber industry of Florida; authors of works on forestry.

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Forest planting.—(By regions.) Trees most likely to succeed in Texas; tree planting in Dakota; trees suitable for forest growth in Louisiana; experimental and mixed planting in Michigan; forest growth advisable for Colorado; forest trees for Dakota; growing forest trees from seed in arid regions; advisable mixture of trees for Texas; trees adapted to Arizona; trees suitable for the arid regions; trees for roadside planting; trees for grove planting in California; trees advised for Illinois; trees for street planting; suggestions on deciduous tree growth without irrigation; timber trees desirable for Minnesota; seacoast planting; instructions for interplanting coniferous seedlings in Minnesota; pecan planting in Georgia; black walnut forest culture; English walnut and pecan culture in New Jersey; treatment of acacia seed in Arizona; treatment of juniper seed in Kansas; trees for shade and ornament in Florida; treatment in pole planting; availability of the ailantus for Kansas; forest planting in Oregon; conifer seeding in Michigan; timber culture

without irrigation in Arapahoe County, Colorado; bamboo planting in Texas and California; climatic conditions for eucalyptus and cottonwood in Central Arizona; black walnut cultivation in Oregon; suitable forest trees for Arizona; reclamation of sand dunes. (By species.) Pinus cembra, its introduction in Maine; osier cultivation; suggestions on growing black walnut; directions for growing seedling conifers; growing cottonwood from seed; maple raising; black walnut planting; black walnut timber, range and cultivation; osier culture in New York and Michigan; acacia seed, its distribution, and value of acacia for tan bark; profitableness of wattles in California; germinating power of catalpa seed in Texas; bamboos, method of propagation; favorable sites for black walnut growing.

Forest management.—Treatment of naturally grown thicket of hard woods; best "works" on trees, their cultivation, etc.; pruning of trees; sumac as material for forest undergrowth; subsoil irrigation; time of transplanting; protection of trees against rabbits; advice on thinning white pine.

Forest botany, etc.—Proper time for gathering and planting seeds of white pine; sprouting of pitch pine; sprouts from conifer stumps; ring growth of trees; quality of wood in different parts of tree; long-leaved pine distinguished from other varieties; discoloration of timber due to fungus growth; locust trees, advice for preventing growth of; varieties of white cedar; hickories indigenous to the United States.

As I have pointed out repeatedly, the character of information expected from this Division is of a twofold nature, namely: technical, in so far as relates to forest management and the production of wood material, and statistical, in so far as the knowledge of the condition of our forest resources may induce application of forestry principles.

Information of the latter kind is needed to influence private activity in the rational utilization of forest supplies, in recuperation of natural forest areas, and in the planting of waste land; more especially, however, to justify the interest and the action of the Government in forestry.

There are three reasons implied why the Government has been induced to establish this Division, and to appropriate funds for forestry work. The first is that, owing to the heavy drains to which our virgin forest supplies are subjected without any provision for recuperation or reforestation, the future of wood supplies may be endangered. The second is that the methods at present followed in utilizing the natural forest areas are destructive, not only of the future forest resources, but also of the cultural and water conditions of the denuded and adjacent territory. A third reason is the desirability from economic considerations (for climatic ameliorations) of encouraging tree growth on the large treeless areas of the United States in the West and on the many places in the East and South which have been made so by irrational treatment on the part of man.

While in regard to the soundness of the third reason there can hardly be any doubt, there has never been a thorough investigation as to the validity of the former two, the work for the Tenth Census being the nearest approach to it.

To establish beyond controversy the fact that our timber supplies as at present utilized are being consumed at a rate more rapid than they are growing would, if at all possible, require a close examination of forest areas, standing merchantable timber, methods of lumbering, the annual drain by cutting, fire, pasturage, and decay, and also capacity for annual reproduction, that we might compare outgo and income.

The hopelessness of accomplishing such a task, especially with the slender means and inadequate organization of this Division, and the doubt whether the expenditure of money and energy in that direction would be fully justified by results, have deterred the Division from entering that field of statistical inquiry. Two years ago it was

proposed to settle the controversy as to available supplies of white pine at least. To accomplish this satisfactorily I estimated that not less than $15,000 would be required. Since then, although nobody can predict the time when this staple will be practically exhausted, indications of its rapid decline have become so unmistakable that an attempt to prove the fact would be needless waste of energy. The time of actual exhaustion of any timber, or of supplies of any particular kind, can never be foretold, for the simple reason that changes in the use of material, substitutes, and various other causes introduce uncertain factors into the calculation.

Several years ago I submitted that, with a resource which, like our forest resource, is determinable by area only, and which can and should be kept in perpetuity by natural reproduction, the rational manner of estimating its condition with reference to the furnishing of supplies is to compare our annual requirements with the possible annual reproduction upon the ascertained area. The area some time ago had been ascertained to be less than 500,000,000 acres of woodlands, capable of yielding at best at the rate of 25 cubic feet of wood per year per acre, or one-half only of what is estimated to be the present consumption annually. In addition to these estimates, which are believed to present the case as nearly correctly as can be done with our knowledge, we have reports from various manufacturers noting the decline of supplies of particular kinds, so that we may conclude that Government interest on the ground of the first reason cited is by no means premature.

It is to be regretted that the opportunity which the machinery provided by the Eleventh Census offered for ascertaining more definitely the present extent and condition of the resource has not been used to its full extent, and that we shall be compelled to remain in comparative ignorance and to reason on surmises or partial knowledge with regard to one of our most valuable controllable resources.

That it should not have been deemed desirable (or only partially so) in the present census to ascertain the condition of a resource which yields raw material of a value not less than one-quarter of the value of all raw materials manufactured will be a surprise to those interested in the forests of the United States.

We should strive to know from decade to decade what changes in the forest areas and their conditions have taken place, just as we ascertain and compare the areas and crops of the agricultural resource. Such knowledge is called for more and more, for commercial purposes, as the area of virgin timber land available shrinks or falls into the few hands which control the lumber supply of the nation.

The call upon the Division to supply information as to where certain kinds of timber may be found in abundance, and as to location of large bodies of merchantable timber, can only be answered in a very general way, hardly satisfactory to the inquirer.

The second reason for Government interest in the forestry question, namely, the effect of unwise denudation upon soil, water flow, and climatic conditions, has been made a continued study by the Division; and while it has not been possible to institute direct experiments or systematic observations which would lead us to a plain demonstration of forest destruction and deterioration of soil or climate or water flow as cause and effect, the results of experiments and experiences in other countries have been published in former reports, and material is constantly gathered of similar experiences

in our own country. The question of forest influences on climate has been carefully studied by Prof. M. W. Harrington, of Ann Arbor, and the results of his investigations into the literature of the subject will be published as soon as opportunity is given.

I may state here that he has mainly occupied himself with a critical scrutiny of the systematic observations in forest meteorology carried on through many years in Europe. The results have been platted in graphic form for ready reference, and the publication will form a desirable basis for further inquiry or experiment, presenting a résumé of what has been definitely accomplished in solving the problem up to date.

My last report contained an analysis of the factors that need consideration in discussing the influence of forest on water supplies, a question which is growing in importance, especially in connection with the irrigation problems of the West.

Granting, then, the existence of sufficient reasons for the interest which the Government has so far taken in the forestry problem, the question every year presents itself anew as to how this interest should manifest itself; for, while it may be easy to recognize the disease, the remedies are not always found at once, and various trials must gradually lead to the selection of those most efficacious.

There are three methods open by which the Government can promote a change in present conditions: First, by placing its own timber holdings under rational treatment; secondly, by direct aid to those who would apply forestry principles in caring for the natural woodlands or in creating new forest areas; and thirdly, by the indirect aid imparted by supplying information.

The total absence of forest management on the timber lands belonging to the United States, nay, the almost total absence of any kind of reasonable management of the same while a forestry division exists in any Department of the Government, is such an incongruity that the influence of the latter must be considerably enfeebled by the reflection that the Government does not act upon its precepts.

The need of a change in this particular—the need of an effective forest administration for the remaining timber lands in the hands of the United States Government—has been pointed out every year in the reports of the Secretaries of the Interior, as well as in those from this Department.

It is the story of the Sibylline books repeated. Every year a part of the domain is wasted by fire, and while thus the value is depreciated without profit to any one, the chance of administering the remainder profitably is diminished. Five years ago I outlined the organization and probable cost of such an administration, and a bill was prepared and laid before Congress which, were it to become law, would enable the population of the Western States, where the Government domain is situated, to obtain their wood supplies in a legitimate manner, while now they are compelled to obtain them by illegal methods. Nor would the mountain sides, as at present, be denuded by fire and ax, not only rendering them waste places but endangering life and property below by giving rise to avalanches and soil-washing torrents, besides rendering the flow of water uncertain.

That the country at large, and especially the region in question, would be benefited by such a forest administration more directly than by any other means, this Division not excepted, must be clear to any unbiased student of the question.

The direct aid which the Government has held out in the interest of forest culture has consisted in permitting the acquisition of Government lands in the treeless regions free of expense, by planting one-sixteenth of the areas to trees, and in charging this Division with the distribution of economic tree seeds and plants.

Both these methods, as practiced, have proved of little avail. As I have shown repeatedly in former reports, to make the distribution of plant material effective it would have to be done on a larger scale than the appropriations for the Division have ever warranted. Hence the distribution had to be confined to small trial packages, which may occasionally assist in spreading an interest in tree growth, but can hardly stimulate forest planting. Other difficulties in this method of Government aid have also been pointed out before. It has also been shown in my last and former reports that the timber-culture entries have in the majority of cases not produced the results for which they were intended. The reasons are various, but mainly, I believe, the frequent failures on the part of bona fide settlers to obtain the required stand of trees, necessitating their abandonment or changing the form of entry. These failures were due to unfavorable climatic conditions and to ignorance of methods and of plant material suited to the localities. This ignorance has been partially overcome by trial, with failure or success, and it may be questioned whether or not in future this method of Government aid could be made more effective by modifying the law, divesting it of its objectionable features, and providing for its proper execution. The repeal of the law failed to be accomplished during the last session of Congress, and I would submit that a revision at this stage of development might be preferable to a repeal.

The third method proposed, by which the Government could be effective in advancing forestry reform, is by disseminating information on the subject. This purpose is subserved by this Division. The kind of information needed, and the methods by which it may be obtained, I have outlined in my last and former reports. I may here only repeat that there is much desirable information which it is impracticable for the Division, as at present constituted and endowed, to obtain, such as the statistics of forest areas, etc., and again other classes of information which can be obtained only by experience, the results of experiment carried on through many years, which, therefore, though not now available, can be made so in time.

The method of imparting the information has been mainly by letter in answer to specific inquiry. The more general information, or such as may be considered complete within certain limits, is embodied in circulars or bulletins. In addition the chief of the Division has supplied addresses, papers, and informal talks to many associations and meetings during the year.

Two circulars, the one giving instructions for the growing of seedlings, and another for the treatment of seedlings in the nursery, were issued during the year. The most important publication during the year has been the final report of Mr. Tratman, promised in my last annual report as Bulletin 4, on the Substitution of Metal for Wood in Railroad Ties, prefaced with a brief discussion by myself on practicable economies in the use of wood for railway purposes. The practicability and ultimate economy, safety, and superiority of metal ties over wooden is proved by reports from all parts of the world, the reports giving the experiences with nearly 25,000 miles of

metal track in actual operation. The need of economy in this use of forest supplies will appear from the figures presented in the bulletin, which show that estimates based on actual returns from almost 60 per cent of the railroad mileage make the amount of wood used for the purpose of railroad building, in round figures, 500,000,000 cubic feet, over four-fifths of which is consumed in railroad ties made from the thriftiest and most valuable timber, namely, oak, chestnut, and pine, with but a small percentage (16 per cent) of cedar, hemlock, cypress, redwood, and other woods. To supply this demand alone continually requires at least 10 per cent of our present forest area. That, even if the use of wood for this purpose be continued, certain economies are desirable and practicable, may also be learned from this report.

From year to year the publication of monographs on the life history of our important conifers has been promised, but always delayed for various reasons. It is hoped that their publication can be accomplished during the coming winter, the illustrations, want of which occasioned the last delay, having been completed. The publication is also expected, without much delay, of a check list of the arborescent flora of the United States. This will form the first of a series of forest botanical papers. The need of such a check list, especially one giving the common names, with their geographical distribution, appeared from the fact that nurserymen, lumbermen, lumber dealers, architects, and others using wood have often been misled by the indiscriminate use of the same names for widely different timbers. It is, for instance, a fact that the users of southern pine in the North are, as a rule, quite uncertain how to order and how to distinguish the three kinds that reach the market, since the same name is applied to each of the different kinds in various regions. Since, lately, the botanists have undertaken to revise the scientific nomenclature also, making the work of the last census, which was used as authority, as well as the botanical text-books, obsolete, it appeared desirable to make and publish the necessary revision in order to establish a basis for intelligent communication. With the aid of botanists throughout the country, who have kindly contributed their notes, it is hoped to unravel the confusion of common names, while the scientific names, that should henceforth stand as authoritative by the law of priority in naming, may be ascertained by reference to the literature of the subject.

This work of revision has proved more laborious and perplexing than was at first anticipated, since even prior revisers were found not to have been successful in all cases, and hence a careful study of authorities became necessary. This work has been diligently pursued by Mr. George B. Sudworth, the botanist of the Division, of whose zeal and efficiency I wish here to express my special recognition. Under his activity the forest botanical herbarium has grown to embody a desirable study material of several thousand specimens. The seed collection for the purpose of identifying the seed of different species now comprises 360 numbers, and a special study collection in alcohol of the buds of our forest trees (some 1,200 specimens of 100 species) has been made and studied with the view of arriving at characters for the ready recognition of our woody plants when without flowers or leaves.

The forest technological investigations referred to in former reports have, by the increase of appropriations, become possible on a scale which was hitherto unattainable. This work, which I desire

to discuss further on more in detail, as planned at present, may be considered the most valuable and promising in which the Division has been engaged since its creation, so far as technical scientific work is concerned. It consists mainly of a thorough examination of our prominent timbers in regard to their technical and physical properties in order to ascertain, if possible, how far these properties depend upon the conditions under which the trees are grown, how far physical properties influence mechanical properties, and also whether a simple method of determining by gross examination of structure the quality of timber can not be devised. The first work in this direction was undertaken to settle a controversy between carriage manufacturers as to the superior value of southern or northern grown oak. The results of the tests and investigations will appear further on. Many similar questions arise constantly, but we have so far only surmises, and no definite basis by which to settle them. The magnitude of the undertaking, the necessity of organized coöperation of various workers to supply each his part in the inquiry, makes this evidently an enterprise worthy of Government direction, and in fact is only practicable under such direction.

WOOD-PULP INDUSTRY.

Various forestry interests have been canvassed by the agents who are assigned to this Division, as yet with incomplete results. The one to which I wish to direct special attention, as referring to the most important development in the use of forest products, relates to the manufacture of wood pulp.

It can be said, without fear of contradiction, that in no field of industrial activity has a more rapid development taken place within the last few years than in that of the use of wood for pulp manufacture. The importance of this comparatively new industry for the present, and still more for the future, can hardly be overestimated. Its expansion during the next few decades may bring revolutionary changes in our wood consumption, due to the new material, cellulose, fiber or wood pulp.

Though rapid in its growth, the industry has by no means reached its full development. Not only is there room for improvements in the processes at present employed, but there are all the time new applications found for the material. While it was in the first place designed to be used in the manufacture of paper only, by various methods of indurating it, its adaptation has become widespread; pails, water pipes, barrels, kitchen utensils, washtubs, bath tubs, washboards, doors, caskets, carriage bodies, floor coverings, furniture and building ornaments, and various other materials are made of it, and while the use of timber has been superseded in shipbuilding, the latest torpedo ram of the Austrian navy received a protective armor of cellulose, and our own new vessels are to be similarly provided. While this armor is to render the effect of shots less disastrous by stopping up leaks, on the other hand bullets for rifle use are made from paper pulp. Of food products, sugar (glucose) and alcohol can be derived from it, and materials resembling leather, cloth, and silk have been successfully manufactured from it. An entire hotel has been lately built in Hamburg, Germany, of material of which pulp forms the basis, and it also forms the basis of a superior lime mortar, fire and water proof, for covering and finishing walls.

According to the manner in which the raw material for the industry shall be secured it may prove either a new enemy to the forest or it may prove a saving element rendering rational and profitable forest management in the United States possible and leading toward it. As I have shown elsewhere, such management in our natural woods depends largely upon the opportunity of marketing wood of small dimensions and inferior material, and this, by an economic development of the pulp manufacture, may be to some extent secured. Self-interest should lead the manufacturers to a study of the problem of forest management for continuous supplies, and mill men should combine with them to have the refuse, slabs, etc., worked up into useful material.

Ten years ago there were in Europe about five hundred wood-pulp establishments, making in round figures 15,000 tons of ground pulp valued at over $5,000,000. With the development of the chemical processes since then it is hardly possible to tell from day to day how fast the production increases. To arrive at an idea how far this industry has developed in this country a canvass has been made among the pulp mills, the results of which have been tabulated below.*

In connection with this, considering the probable importance of the subject to forestry interests, it may be desirable to explain briefly the various processes, their advantages and disadvantages, their significance in connection with our forest resources, and to add suggestions which may be helpful in the development of the industry.

In the following brief statements I have followed, in part, the excellent résumé of the present state of the chemico-technical use of wood by the referee at the Vienna International Agricultural and Forestry Congress, where, if a more liberal policy had permitted a representation from this Department, probably much of additional value in this and other lines might have been learned. For the chemical reactions the recently published Dictionary of Applied Chemistry, by T. E. Thorp (1890), has alto been consulted.

It may first be stated that cellulose is the preponderating constituent of all vegetable tissues; in fact, elaboration of cellulose is synonymous with growth. In addition to the cellulose there are present in the wood nitrogenous substances, resins, gums, and (mineral) ash, which are to be removed, more or less, in order to produce the fiber or pulp. To do this economically and in such a manner that the fiber may remain long, pure, and white and the mass preserve its "felting" qualities as much as possible, is the aim of the various processes.

About half of the wood substance consists of cellulose, the soft woods containing, however, more than the hard woods; one reason why the former are preferred in the commercial production of pulp.†

* The first suggestion to use fiber for paper manufacture was made by a German, Jac. Christ. Schaeffer, in 1772; the first patent of commercial importance for chemical production was obtained by Watts & Burgess in 1853, and a small mill erected in London about 1855; the first large pulp mill was established in Manayunk, near Philadelphia, in 1865; in 1868 in England, in 1871 in Sweden, and soon afterward in Germany, where the modern processes have been mostly developed.

† The following percentages of cellulose in air-dried wood were determined by chemical analysis:

Poplar	62.8	Basswood	53
Fir	57	Chestnut	52.6
Willow	56.7	Locust	48.4
Birch	55.5	Beech	45.5
Pine	53.3	Oak	39.5 (45.9)

There may be now distinguished three classes of wood pulp, according to the manner of its manufacture, namely, mechanical, pseudo-chemical, and truly chemical pulp.

The preliminary preparation of the wood is the same for the different processes. It includes the cutting and splitting to suitable size for handling, the removing of the bark on the "barker" (a planing mill with two blades, or other contrivance); the removing of knots by the "knotter," an auger, and the removing of the pith by the pith cleaner, when necessary. For the chemical processes a further preparatory operation consists in the "chipping," which is done by knives placed on the face of cylinders, 5 feet in diameter, making 150 revolutions, having a bite of one-eighth inch; the "chips" are further reduced mechanically by crushing rolls, after any knots and discolored pieces have been picked out from the moving apron which carries the chips from the chipper to the rolls.

(1) The *mechanical or ground pulp* is produced by grinding the wood, after proper preparation, on rapidly rotating stones under constant flow of water (Voelter process). For this process round wood is used of 4 to 8 inches diameter, cut into lengths of 10 to 20 inches, according to the face of the grindstones against which the wood is pressed lengthwise with the fiber.

Emery-wheel cutters, using 40-horse power, will produce 50 pounds per hour of dry pulp, while natural stones, producing 25 per cent more pulp, require more than double the power. The ground mass, looking like thin gruel, is pumped into tanks, screened into vats, and then run off in thick sheets on the "wet machines" on which it is dried, folded, and pressed, containing still at this stage 60 per cent of water.

(2) *Brown wood pulp* is mainly a mechanical pulp, except that the wood is steamed before grinding, under a pressure of 2 to 6 atmospheres. This steaming, with a heat at 300° Fahr., produces a chemical reaction, the soluble nonvolatile ingredients of the wood forming powerfully acid bodies which aid in the separation of the fiber; their corrosive action makes it necessary to use for the digesters vessels lined with copper or lead. After the wood is steamed, it is ground between millstones or in a rag engine (system Rasch & Kirchner). To avoid the acid reaction, and the necessity of noncorroding vessel linings, the addition of neutral sulphites has been proposed, when the organic acids combining with the base are neutralized, a sulphite residue remaining. A sodium sulphite solution (5 per cent Na_2SO_3) with a high temperature, 356° Fahr., is used, the action of which, besides neutralizing the acids, seems mainly to consist in keeping the path open for continued action of the heat and water. It is claimed that this latter process has disadvantages in point of economy.

(3) *Chemical wood pulp*, or cellulose proper (in this country called chemical fiber), is produced by treating finely divided wood or wood shavings with various chemicals, which dissolve or render soluble the incrusting substances, leaving the fiber as long, elastic, and pure as the raw material will furnish it, while the above mechanical processes naturally shorten and deteriorate the fiber mechanically.

The chemical processes can be again classified into alkaline and acid processes, according to the kind of chemicals used. Of the many methods proposed only four or five have been developed with industrial success.

All these processes have in common the mechanical preparation of the wood, as described before, preceding the boiling with chemicals under pressure (which requires hermetically closed digesters, with anticorrosive linings) and subsequent washing out of the residual solution, screening, draining, and drying on "wet machines," and most of them, to produce the desirable white color, require a special bleaching process. The partial manufacture of the solvents and the recovery of the spent liquor of solution, or else its treatment for other useful materials, forms also part of the processes. Since the chemicals are apt to attack the fiber itself, a careful adjustment of their proportions is essential, otherwise the loss of

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While these are laboratory results of European chemists, the following percentages, given by Charles M. Cresson, relate probably to pulping results:

Hemlock	45	Spruce	32
Walnut (very dry)	42	Cherry	32
Birch	40	Chestnut	30
Poplar (seasoned)	37	Hickory	22.6
Poplar (unseasoned)	30	Maple (unseasoned)	21.2
Yellow pine	36.5	Ash and oak (unseasoned)	20.6
White pine	33.25		

The general practice brings out still smaller results.

yield may increase unduly. The drying, after the processes of purification, is also an important part, since it is to be considered not a mere desiccation, but a chemical reaction, which, if not properly conducted, results in hardening and agglutination of the fiber.

Of alkaline processes there are two prominent:

(*a*) *Soda pulp* is produced when caustic soda lye under pressure and steam heat of 300° to 360° is used to remove the incrusting substances, carbonate of soda or solway salt and caustic lime being used to obtain the caustic soda, which can be easily and cheaply recovered by evaporation and calcination, the dissolved organic matter supplying the fuel for the latter part of the process of recovery. About 75 to 80 per cent is thus recovered as "black ash." The tank wastage, consisting of lime, silicates, and impurities, is apt to become a nuisance, if allowed to flow off into rivers, etc. The strength of solution, proportion of it to the material, temperature and duration of the digestion vary considerably with different woods. The chemical changes are very complex and as the chemical action extends to the cellulose itself, the yield is thereby reduced.

(*b*) *Sulphate pulp* results from digesting the wood at a temperature of 300° to 360° in an alkaline mixture in which sulphates preponderate. This process, which is successfully worked in Europe, but seems unknown in this country, contains several points of economic importance. The liquor is made by treating sodium sulphate (glauber salts, 90 pounds of sulphate to 100 pounds of dry pulp) with caustic lime, when a certain proportion of the former is transformed into caustic soda. The liquor, after the boiling, is evaporated, calcined, and treated with lime, by which it is recovered as sulphide and hydrate (caustic soda) in nearly equal proportions, together with some sulphate; and with the addition of some sulphate (about 20 per cent) to compensate for the unavoidable loss, the cycle of operation is kept up.

The pulp from this process is of very high quality, similar if not superior to soda pulp, the only objection being that in consequence of the presence of some organic sulphur compounds it is somewhat malodorous, which, however, it might be possible to overcome. With cheap materials to begin with and easy recovery of the liquor this should prove a very economic process. It is really almost the same as the one described as soda pulp, only that instead of buying the more expensive caustic soda, this is obtained in the process itself from cheaper and more easily transported materials. A recent patent by G. Hessee proposes boiling the wood with bisulphate of soda, then grinding the wood and using the spent liquor for the manufacture of sugar and alcohol.

The acid processes are more numerous and have come lately more to the front. Passing by the Bachet-Machard process, which, using dilute hydrochloric acid, was employed in Switzerland for making coarse packing paper, and the Tilghman-Pictet process, employing sulphurous acid in lead-lined vessels, we come to the so-called (*c*) *sulphite pulp* which is obtained when removing the incrusting substances by boiling the wood with acid sulphurous salts like the acid sulphite of lime Ca $(HSO_3)_2$), or bisulphite of lime and magnesia $\binom{ca}{m}$ $(HSO_3)_4$). The various processes of this class (developed by Tilghman, Mitscherlich, Ekman, Francke, Graham, Macdougall, Flodquist, Kellner, and others) are identical in principle and differ only in technical detail. The boiling liquors vary in regard to acid strength (3 to 5 per cent) and proportion of base, temperature, and duration of digestion (300° to 350° and thirty to eight hours). Various woods require, of course, variation in strength of liquor, etc. All require special apparatus protected against the corrosive action of acids by a lead or other (special brick) lining. There are also digesters in use made of a bronze metal which resists the corrosion.

Under a recent patent (F. Salomon) a serviceable lining is obtained by heating the vessel filled with sulphite liquor or gypsum solution, which, when boiling, will deposit a durable crust. This crust, which forms itself during the process anyhow, used to be considered a nuisance, as it resisted removal, until it was discovered that its presence answered as a protective lining. It is claimed to be safer than the combined brick and lead lining for the reason that the latter is hidden from possible inspection, and any leaks occurring unforeseen give rise to explosions. The same patentee proposes several other methods of lining.

The source of the acid liquor is either sulphur or pyrites, burnt in suitable ovens, the fumes being led into towers ("acid towers"), where a constant, well-distributed supply of water flows over and through columns of basic material (calcined magnesia or lime) or a milky mixture of the latter agitated in special apparatus, the reaction in both cases resulting in bisulphate of lime, which collects at the bottom of the tower; from here it is led to the digesters (1,400 to 1,800 cubic feet capacity), in which the wood chips have been steamed before for five or six hours to soften them. The digesters, either stationary or rotary, are now filled up, nearly, with the bisulphite and the temperature raised to 225° and after a certain stage to 265°, at

which is kept until near the close of the process when it drops again to 220°, the boiling lasting for thirty to fifty hours. The liquor is then drawn off, the acid washed out of the pulp in vats under constant agitation, sifted, drained, and dried.

While the lime needed in the process is found almost anywhere—magnesite, which is found in California, and the dolomites, which are found more generally, and react more readily—the sulphurous constituents are not as easily obtainable. The supply of sulphur for the United States comes mainly from Sicily, although sulphur mines are opened in Utah near Salt Lake and in Humboldt County, Nevada (Rabbit Hole Mountain). Pyrite ores, which form the principal native source of sulphurous acid, are mined at Capleton, Connecticut; Elizabeth Mine, Vermont; Rowe, Massachusetts; Mineral City (formerly Tolersville), Virginia; and several localities in Georgia; also in Novia Scotia and on the north shore of Lake Superior (Sudbury), and in the Western States.

It is suggested that the sulphurous products from the roasting of copper ores and of zinc blende ores might be utilized, the latter being found largely in Southwest Missouri (Joplin) and Southeastern Kansas (Galena), Southern Wisconsin and Illinois (La Salle). It is also suggested that the gas works lime might be worked over for the sulphur it contains.

The residue from the process, sulphate of lime with resin gums, etc., combined, is of no value.

The outlay for mill and machinery in this process is said to range from $5,000 to $15,000 for each ton of daily product, and the cost of manufacture $30 per ton.

(*d*) *Electro pulp* is a product of most recent processes (developed by C. Kellner), in which the wood is digested in a solution of common salt at 250° to 260°, constantly electrolyzed.

Two digestors in communication are employed and the liquid is kept in continuous circulation from the electrolyzing vessel over the wood in the digesters and back to the electrolyzer, the latter a separate vessel in communication by means of pipes with both digesters.

The electric action splits up the salt into caustic soda and chlor-oxygen compounds; these latter, of well-known bleaching power, make the usual subsequent bleaching unnecessary and the process is said to furnish at once a "snow white" fiber. Under this class of processes belong also those pulping processes which employ chlorine gas as a disintegrator rather than a bleaching agent. The effect of the chlorine gas or its active oxygen compounds is to oxidize the incrusting substances so that they become soluble in very dilute alkali liquors without the need of higher temperatures.

The bleaching is done, as a rule, by the use of hyposulphite or bleaching powder, which is mixed with the pulp in varying quantities.

Lately an electro-chemical bleaching process (E. hermite) seems to have been brought to perfection, in which a weak (5 per cent) solution of magnesium chloride is electrolyzed. The chlorine developed acts as a bleacher and then combines again with the base, so that the same liquor can be used over and over again, the cost of the motive power for the electric machine being the only expense. The elaborate plant is objected to. (See Journal of Society of Chemical Industry, London, 1890, containing one paper in vindication (Cross & Bevan), and another against the process (Hurter). A further improvement of this process consists in adding a small proportion of quicklime to the salt solution, whereby it is claimed the electro-motive force may be reduced and other advantages gained.

To estimate the commercial value of these various processes three points, it seems, ought to be considered: (1) The resulting product as to quality and yield; (2) the cheapness and convenience of the necessary plant and chemicals; (3) the application to various woods.

Ample water power and clear water, supply of suitable woods with large proportion of cellulose, long felting fiber, and requiring least expense in freeing it from incrustations, are the conditions, in addition to those which favor any other commercial enterprises, to be looked for in locating plants. I would especially point out in the interest of forest management and forest supplies that an adaptation of the plant to the simultaneous use of the various woods offered, combining those of long and short fiber, will have to be the study of the future.

The material obtained by the different processes differs in quality and quantity and answers different purposes.

The *ground pulp* is naturally of short fiber, and while without addition of a long, elastic, and felting fiber, only short (brittle) paper can be made from it, for a filling material of better classes of pulp in the manufacture of ordinary cheap paper and cardboard it answers very well, giving body and capacity. Common newspaper consists of 80 per cent of ground pulp.

The yield should be 1 pound per horse power per hour of dry stuff and about 19 pounds per cubic foot of wood where spruce and fir are used. The larger yield reported—namely, 2,000 pounds to the cord—refers either to a very well measured cord or else to material not thoroughly air-dried. The plant is naturally cheap and with pure water and sufficient fall of the same is easily put up and run economically. The wood need not be as clean as for the chemical processes, inferior material being satisfactory, although branch knots must be removed as they discolor the pulp, and rotton wood can not be used. The better class of firewood answers very well. All woods can be used for this process, but the harder woods require more power, and hence are less economically worked, so that now mostly conifers are ground; also aspen, poplar, cottonwood, basswood, birch, buckeye, and gum.

The *brown pulp*, which seems not to be made in this country, yields a much longer and better felting fiber, since by the steaming process a part of the incrustation is dissolved and the fibers are loosened, and hence not so much lacerated in the grinding. Since, however, the dissolved compounds impart a dark color to the pulp, it can be used only for brown papers. It makes, however, an excellent, tough packing paper and strong pasteboard. Attempts to remove the brown color by boiling in dilute oxalic acid have so far been only partially successful. A process by which the wood is boiled in hydrosulphuric alkalis with subsequent washing in hot water seems to be more successful in yielding a whiter material capable of treatment with bleaching powder. The salts can be recovered and used again, while the brown liquor of solved materials may be worked advantageously for wood alcohol, so that this process promises much economy. The yield of pulp under favorable conditions is said to be as high as 70 per cent in weight of the wood, which is the highest claimed for any process.

The chemical processes furnish the best material, but since the chemicals under higher temperatures attack and dissolve part of the cellulose itself, the yield is considerably less than from the mechanical and partly chemical processes. While the electric process is as yet in its infancy, there can hardly be any doubt that it will be rapidly developed and eventually supersede all other processes, since it involves no other expenditure than that for motive power and promises to yield a superior product.

The *soda pulp* is similar to that from cotton rags, of greater softness and opacity than the acid pulps, but the yield is rather low on account of the strong action of the chemicals on the cellulose; thus, while the bisulphate may yield 45 to 50 per cent from white pine, the soda process would yield only 33 per cent, or 800 to 1,000 pounds per cord. The present low cost of soda and the easy and cheap method of recovery from the spent liquor by evaporation and calcination, in which latter operation the fuel is supplied by the dissolved organic matter, are factors of economy which may offset the lower yield.

The *sulphate pulp* yields a paper similar in quality to that from soda pulp, perhaps somewhat better, approaching linen paper. The

objectionable smell and the economic features of this process have been pointed out before. The absence of tank wastage is particularly noticeable. It is also claimed that it bleaches far better and with half as much bleaching material as other processes in the market. It is probably classed with either soda or sulphite pulps.

The *sulphite pulp* is harder and more transparent than the pulp obtained by alkaline treatment. It may be used without further bleaching for tinted and low white paper, but to produce a fully white material like soda pulp 15 to 30 per cent its own weight of bleaching powder is required. The yield should be 40 to 50 per cent, but from the reports it would appear that the practice in this country brings hardly more than the soda process. With the residual liquor an entire loss, and no special features of superiority, it is questionable whether this process, although at present on a boom and enormously extended, will ultimately maintain its high position. Especially when it is considered with reference to wood supplies, it can not be expected to supersede the alkaline processes.

ADAPTATION OF WOODS.

The soda and sulphate processes can utilize much more resinous and knotty woods or parts of trees because the resins combine with the alkalies to form soaps soluble in water and hence easily washed out, while the acid processes, like the sulphite, dissolve the resins only partially, and are, therefore, preferably used for young growth and sapwood, leaving the older heartwood intact, although it is claimed that the knots in spruce and balsam fir soften as readily as the rest of the wood; but the heart of the Norway pine and probably of the more resinous pines of the South would not yield to this treatment.

The fibers of conifers resemble those of cotton, are of considerable length, flat, tape-like, and flexible, which characteristics impart to them superior felting quality.

The deciduous woods are most readily acted upon by the solving liquids, and some of them, poplar, aspen, tulip, and basswood, especially excel by their white color; they would, therefore, form a most desirable raw material if their shorter fiber were not objectionable. The cells being in the average only about one-tenth of an inch in length, tubular and pointed, they do not make a good felting pulp, although they are quite flexible, and hence even the chemical pulp of these woods, with few exceptions, is used only as filler. A further study of our native hard woods, with reference to their fiber, is, however, still desirable before classing them all as second for pulp material.

The poplars, which have the longest fibers of those so far used, have the advantage of a persistent white color, while basswood, next in value, takes a reddish tint, birch a pink, and maple a purple hue, which makes it objectionable; larch is said to color very badly. Spruce, balsam fir, hemlock, jack pine, cedar in the North, loblolly pine, and cypress in the South are at present staples. The spruce especially furnishes at present the bulk of pulp manufactured in this country, a frequent practice being to add some poplar or aspen pulp for the purpose of whitening the spruce pulp.

It is said that trees twenty-five to thirty years old are best for grinding, that evenly grown wood is the most desirable, and that trees from marshy ground are not acceptable. The wood must be

freshly cut, as too much exposure to the air hardens the fiber by drying. By keeping the wood in the water until ready to use it, not only is it kept softer, but some of the resinous substances are leached out.

If prices give a correct estimate of values, the chemical pulp is about two and two-thirds times superior to mechanical pulp. For the sake of comparison the following quotations are here given:

	At London.	At New York.	Domestic.	Tariff.
Ground pulp (pine), dry, per ton	$24.00	$30.00	....	....
Ground pulp (aspen), dry, per ton	40.00	35.00	$26.00–28.00	$2.50
Brown pulp, dry, per ton	30.00	....	....	....
Soda unbleached	$00.00–60.00	$54.00–61.00	....	6.00
Soda bleached	67.50	70.00–78.00	70.00–75.00	7.00
Sulphite unbleached	50.00–75.00	54.00–71.00	75.00–80.00	6.00
Sulphite bleached	82.00–88.00	85.00–95.00	90.00–100.00	7.00
Wood flour	....	27.00	30.00	....

Making the average yield per cord 1,700 pounds for ground, 1,000 for sulphite, and 800 for soda pulp. By the different processes the value of a cord of wood may be brought to $24.50 or $30, respectively.

From the compilations of the Paper Trade Journal (Howard Lockwood, New York), the growth of the industry for the last nine years can be learned:

Growth of daily capacity of running wood-pulp manufacture.

	Chemical fiber.	Ground wood pulp.
	Pounds.	*Pounds.*
1881	259,500	484,300
1883	466,000	633,450
1884	576,000	795,550
1885	587,000	835,830
1886	537,000	960,600
1887	602,000	1,085,900
1888	617,000	1,536,500
1889	866,500	2,607,600
1890	1,376,500	2,900,700

This would show that the business has increased nearly 500 per cent in the last eight years and nearly 200 per cent in the last four years.

In 1888 the stumpage consumed for pulp was valued at $2,235,000. The product, 225,000 tons ground and 112,500 chemical pulp, was valued together at $12,375,000, the capital employed being estimated at $20,000,000. The figures given below would indicate a present consumption in round numbers of 1,000,000 cords of wood per annum. When it is considered that about 1,000,000,000 pounds of book and news paper are consumed annually in this country, two-thirds of which might be made of wood fiber, there is still a considerable margin for this use alone to be supplied by wood pulp.

In reply to the question what the Department might do for the pulp makers' interests, the need of stopping the firing of the woods is most prominently mentioned. The planting of trees, bounty for such planting, or distribution of plant material, are also suggested. Railroad facilities, tariff protection, and reports giving reliable information are asked for by others.

Statistics of the wood pulp industry of the United States, 1890.

(*a*) NUMBER OF MILLS IN OPERATION AND THEIR CAPACITY.

States.	Mechanical (ground) pulp.			Chemical (soda) fiber.			Chemical (sulphite) fiber.			Mechanical and chemical combined.		Total.	
	Number of mills.	Capacity, daily.		Number of mills.	Capacity, daily.		Number of mills.	Capacity, daily.		Number of mills.	Capacity, daily.	Number.	Capacity.
		Range in 1,000 pounds.	Total.		Range in 1,000 pounds.	Total.		Range in 1,000 pounds.	Total.				
Maine	15	2.5–70	407,500	4	20–52	149,000	5	16–30	106,000	...	...	24	662,500
New Hampshire	15	4–30	220,500	2	60	60,000	1	10	10,000	...	...	18	290,500
Vermont	17	2–80	273,500	...	...	...	1	8	8,000	...	...	18	281,500
Massachusetts	3	4–10	21,000	1	11	11,000	3	8–20	43,000	1	40,000	8	115,000
Connecticut	...	...	...	...	...	...	1	...	11,000	...	...	1	11,000
New York	67	1.5–80	855,800	4	8–55	117,000	3	16–30	76,000	1	6,500	75	1,055,300
Pennsylvania	3	6–20	42,000	7	6–80	233,000	1	...	25,000	...	...	11	300,000
Delaware	...	...	...	1	44	44,000	...	...	...	...	...	1	44,000
Maryland	1	25	25,000	1	27	27,000	1	...	20,000	...	...	3	72,000
Virginia	2	12–18	30,000	...	...	...	...	...	...	...	...	2	30,000
West Virginia	3	30–30	84,000	...	...	...	1	...	50,000	...	...	4	134,000
North Carolina	3	...	7,000	...	...	...	...	...	...	...	...	3	7,000
South Carolina	1	...	2,500	...	...	...	...	...	...	...	...	1	2,500
Georgia	5	.6–4	11,850	...	...	...	...	...	...	...	...	5	11,850
Kentucky	1	...	22,000	...	...	...	...	...	...	...	...	1	22,000
Ohio	2	8–10	30,000	1	...	7,500	2	...	30,000	...	...	5	67,500
Indiana	11	1.5–40	129,500	1	...	30,000	...	...	...	...	...	12	159,500
Michigan	8	3–24	67,000	1	...	8,500	4	4–30	72,000	...	...	13	147,500
Wisconsin	21	6–30	310,000	...	...	...	5	...	74,000	...	...	26	384,000
Minnesota	2	2–20	22,000	...	...	...	...	...	...	...	...	2	22,000
Oregon	2	8–40	48,000	...	...	...	1	...	20,000	...	...	3	68,000
California	1	...	40,000	...	...	...	...	...	...	...	...	1	40,000
Total	183	...	2,649,150	23	...	687,000	29	...	545,000	2	46,500	237	3,927,650

NOTE.—In addition to the above 237 mills, which number represent nearly all at present in operation, there are reported 14 idle and 2 abandoned. From Canada 33 pulp mills are reported, 24 of which have a daily capacity of 276,800 pounds.

(*b*) SUPPLIES AND PRODUCT.

States.	Number of mills.	Kinds of wood used.	Range of yield, per cord, in hundreds of pounds.			Number of mills reporting supplies.					Remarks.
			Mechanical.	Soda.	Sulphite.	Good.	Fair.	Limited.	Declining.	Poor.	
Maine	12	Spruce only or chiefly	16–20	...	11–13.5	20	1	..	..	..	
	7	Spruce and poplar	15–20	10	...	..	..	..	..	..	
	1	Spruce, poplar, and pine	...	...	...	..	..	..	..	..	
	1	Poplar	...	10.3	...	..	..	..	..	..	
New Hampshire.	13	Spruce only or chiefly	18–24.5	...	10	11	2	2	..	..	1 get supplies mostly from Canada.
	2	Spruce and poplar	...	10	...	..	..	..	..	..	2 get supplies partly from Canada.
Vermont	11	Spruce only or chiefly	18–20	...	...	11	..	4	1	1	1 get supplies mostly from Canada.
	5	Spruce and poplar	20–23	...	...	..	..	..	..	..	
	1	Poplar and pine	20	...	...	..	..	..	..	..	
Massachusetts.	4	Spruce only or chiefly	15–22	...	10	5	..	..	..	3	2 supplies from northern Vermont and New Hampshire.
	4	Spruce and poplar	17–18	...	...	..	..	..	..	..	

Statistics of the wood pulp industry of the United States, 1890—Continued.

(*b*) SUPPLIES AND PRODUCT—Continued.

States.	Number of mills.	Kinds of wood used.	Range of yield, per cord, in hundreds of pounds.			Number of mills reporting supplies.					Remarks.
			Mechanical.	Soda.	Sulphite.	Good.	Fair.	Limited.	Declining.	Poor.	
Connecticut	1	Spruce								1	Supplies from New Brunswick and Nova Scotia.
New York	52	Spruce only or chiefly	15–22		13	34	7	8	2	2	1 supplies mostly from Canada.
	4	Spruce and poplar	16–20								15 supplies from Canada or distant points.
	1	Spruce and hemlock			11						
	1	Spruce, hemlock, bass			10						
	2	Spruce, poplar, and pine									
	2	Poplar	14	9							
	1	Poplar, bass, pine, and spruce.		10							
	1	Spruce and pine									
Pennsylvania	2	Spruce only or chiefly	19–20			1		1			
	1	Spruce and poplar			10					1	Supply from West Virginia and Nova Scotia.
	2	Poplar		10						2	Supply from Maryland and Virginia.
	2	Poplar, bass, pine		9–10			2				
	2	Poplar, bass, pine, maple		7–12			2				
	1	Hemlock, pine, beech, bass.		10		1					
	1	White pine	16			1					
Maryland	2	Spruce only or chiefly	18		10	1	1				Spruce from West Virginia and Canada.
	1	Poplar		10		1					
Delaware	1	....do						1			
Virginia	2	....do	20			2					
West Virginia	4	Spruce only or chiefly	17		10.5	2	2				
North Carolina	2	Pine	10				2				
South Carolina	1	Cypress and gum					1				
Georgia	3	Pine	20–27			3					
	1	Cypress and gum				1					
	1										
Kentucky	1	Spruce, buckeye, and maple.	18				1				
Ohio	2	Spruce only or chiefly	17			2					
	1	Cottonwood and bass		9	10		1				
Indiana	3	Aspen	16			1		1		1	
	1	Spruce and poplar	16				1				
	2	Poplar, spruce, pine	12					1		2	
	1	Aspen, poplar, cottonwood.	10							1	
	1	Cottonwood	20					1			
	1	Basswood		9		1					
Michigan	4	Spruce only or chiefly	16		8–10	1	2			1	1 supply all from Canada.
	3	Poplar	16–20	15		2		1			
	4	Poplar, pine, tamarac, spruce, and balsam.				4					
	1	Aspen, pine, poplar, spruce, and bass.	14						1		
Wisconsin	4	Spruce only or chiefly.	16–18		9–10	1	2		1		
	15	Spruce and poplar	13–15		9–10	5	5	2	1	2	
	4	Spruce, poplar, pine	10–12			1		1	2		
Minnesota	1	Spruce only or chiefly	15					1			
Oregon	1	Cottonwood				1					
California	1	Tamarac and fir	17			1					

TIMBER TESTS.

While the use of wood pulp and other substitutes may displace in many ways the use of wood in its natural state, there will always be desirable qualities inherent in the latter that make its use indispensable. Hence the desirability of knowing the qualities of our timbers, and, if possible, of knowing the conditions under which the wood crop will develop the desirable qualities.

Much work and useful work is done in the world by the rule of thumb. All such work is not reliable and certainly not economical. With the need of greater economy in production, the need of more accurate measuring arises, and with that the need of more specific knowledge of the materials to be measured.

Wood is one of the materials which has been measured by the rule of thumb longer than others. Iron and other metals used in the arts have their properties much more accurately determined than wood material. Especially in the United States, when we speak of quality of our timbers, it can only be in general terms ; we lack definite data.

One difficulty in determining reliably the qualities of our timbers lies in the fact that living things are rarely precisely alike. Every tree differs from every other tree, and the material taken from the one has a different value from that taken from the other of the same species. Yet every tree has some characteristics in common with all those grown under similar conditions. But even these common properties differ in degree in different individuals. Individual variation tends to obscure relationship.

The factors which determine the quality of timbers are found directly in the structure of the wood, and it is possible from a mere ocular examination to judge to some extent what qualities may be expected from a given piece of timber, although even in this direction our knowledge is very incomplete, and but few definite relations between structure and quality, or between physical and mechanical properties, are established. We know that the width of the annual rings, their even growth, the closeness of grain, the length, number, thickness, and distribution of the various cell elements, the weight, and many other physical appearances and properties of the wood influence its quality, yet the exact relation of these is but little studied. Conjectures more or less plausible, suppositions, and a few practical experiences preponderate over positive knowledge and results of experiments. Again we know, in a general way, that structure and composition of the wood must depend upon the conditions of soil, climate, and surroundings under which the tree is grown, but there are only few definite relations established. We are largely ignorant as to the nature of our wood crop, and still more so as to the conditions necessary to produce desirable qualities, and since forestry is not so much concerned in producing trees as in producing quality in trees, to acquire or at least enlarge this knowledge must be one of the first and most desirable undertakings in which this Division can engage.

Accordingly a comprehensive plan has been put into operation to study systematically our more important timber trees.

It will at once be understood that as long as the qualities are to be referred to the conditions under which the tree is grown the collection of the study material must be made with the greatest care,

and the material must be accompanied with an exhaustive description of these conditions. Since, further, so much individual variation seems to exist in trees grown under seemingly the same conditions, a large number must be studied in order to arrive at reliable average values. For the present it has been decided to study the pines, especially the white pine and the three southern lumber pines.

In selecting localities for collecting specimens, a distinction is made between station and site.

By station is understood a section of country (or any places within that section) which is characterized in a general way by similar climatic conditions and geological formation. Station, then, refers mainly to the general geographical situation. Site refers to the local conditions and surroundings within the station, such as difference of elevation, of exposure, of physical properties and depth of the soil, nature of subsoil, and forest conditions, such as mixed or pure growth, open or close stand, etc.

The selection of characteristic sites in each station requires considerable judgment.

On each site five full-grown trees are to be taken, four of which are to be representative average trees; the fifth or "check" tree, however, should be the best developed tree that can be found on the site. Some additional test trees will be taken from the open and also a few younger trees. The trees are cut into varying lengths, and from each log a disk of 6-inch height is secured after having marked the north and south sides and noted the position of the log in the tree.

The disks are sent for examination of the physical and physiological features to the Michigan University, while the logs, and later on special parts of the disks are to be sent to the test laboratory of the Washington University of St. Louis. Here, for the first time, a systematic series of beam tests will be made and compared with the tests on the usual small laboratory test pieces. Such tests with full length beams in comparison with tests on small specimens promise important practical results, for a few tests have lately developed the fact that large timbers have but little more than one-half the strength they were credited with by standard authorities, who relied upon the tests on small specimens.

From the "check" tree mentioned before only clear timber is to be chosen, in order to ascertain the possibilities of the species and also to establish, if possible, a relation between such clear timber and that used in general practice, where elements of weakness are introduced by knots and other blemishes.

An authority on engineering matters writes regarding this work:

> Inasmuch as what passes current among engineers and architects as information on the strength of timber is really misinformation, and that no rational designing in timber can be done until something more reliable is furnished in this direction, the necessity for making a competent and trustworthy series of such tests is apparent. This is a work which the Government should undertake if it is to be impartial and general.

A careful record of all that pertains to the history and conditions of the growth from which the test pieces come, and of their minute physical examination, will distinguish these tests from any hitherto undertaken on American timbers.

The disk pieces will be studied to ascertain the form and dimensions of the trunk, the rate and mode of its growth, the density of the wood, the amount of water in the fresh wood, the shrinkage consequent upon drying, the structure of the wood in greatest detail,

the strength, resistance, and working qualities of the wood, and lastly, its chemical constituents, fuel value, and composition of the ash.

For this part of the work, which is the most laborious and difficult, Mr. Filibert Roth, of Ann Arbor, is engaged, having prepared himself for it by several years of preliminary study in that line. The testing will be done by Prof. J. B. Johnson, of St. Louis, whose facilities, central location, and interest in the work promise desirable progress. The collection of the southern pine specimens, which will occupy the greater attention of the work this year, is done by Dr. Charles Mohr, which assures a judicious selection of material and competent description of conditions of growth.

Thanks are due to the Louisville and Nashville Railroad Company and to the Chicago, Milwaukee and St. Paul Railroad and to the Chicago, Burlington and Quincy Railroad Companies, who in a generous manner have offered free transportation for test logs.

It is estimated that for the first series fifty trees will be studied, involving about two thousand tests and a large amount of laboratory determinations.

Incidentally with this line of work, at the request of the Committee on Timber Supply of the National Carriage Builders' Association, some tests of northern and southern grown oak for carriage stock were undertaken, the results of which are here reported.

Unfortunately it was not possible to secure the test material, or to carry out the tests as thoroughly as should have been done, in time for the desired report to the Carriage Builders' Convention. The following tests and examinations, therefore, are not to be considered as samples of what will be done, but only as indications of the kind of questions to be settled by this inquiry. It will be found that the descriptive part is not what it should be, and the number of tests is too small to allow generalization, yet some interesting results are nevertheless anticipated from these preliminary tests.

In the descriptive part the schedule, which is to be filled out for the more elaborate tests, is given in full in order to establish uniformity in description. A series of descriptive words appear in the schedule (as given for sample *a*), so that the collector needs only to underscore the suitable one.

(*a*) *Description of station, site, and trees from which test material was taken.*

I. Station:	A (Connecticut).	A	B (Arkansas).
1. Average longitude....	73.		91.
2. Average latitude.....	41.30.		36.
3. Average altitude.....	200 (?)		
4. General configuration.	Plain, hills, plateau, mountainous, general trend of valleys or hills.		
5. Climatic features.			
II. Site:	*a*.	*b*.	
1. Aspect	Level, ravine, cove, bench, slope (angle of).		Specimens selected from stock in the yard of Woody, Holmes & Co., carriage stock manufacturers. History unknown. Supposed to represent fair average of first-class timbers that can be supplied in large quantities.
2. Exposure.			
3. Elevation above average station altitude.			
4. Soil conditions......	Upland	Lowland....	
(*a*) Geological formations.			
(*b*) Mineral compositions.	Clay, limestone, loam, marl, sandy loam, loamy sand, sand.		
(*c*) Surface cover....	Bare, grassy, mossy; leaf cover abundant, scanty, lacking.		
(*d*) Vegetable mold, depth.			

(a) Description of station, site, and trees from which test material was taken—Continued.

II. Site—Continued.			
4. Soil conditions—Continued.			
(*e*) Grain, consistency, and admixtures.	Very fine, fine, medium, coarse, porous, light, loose, moderately loose, compact, binding, stones or rocks (size of).		
(*f*) Moisture conditions.	Wet, moist, fresh, dry, arid, *well drained*, liable to overflow, swampy, near stream or spring or other kind of water supply.	Wet	
(*g*) Color			
(*h*) Depth to subsoil	Shallow, 6 inches to 1 foot; 1 foot to 4 feet, deep; over 4 feet, very deep; shifting.		
(*i*) Nature of subsoil			
5. Forest conditions:			
(*a*) Growth	Mixed, pure, dense, moderately dense, open.		
(*b*) Associated species			
(*c*) Proportion of these.			
(*d*) Average height			
(*e*) Undergrowth			
6. Conditions in the open			
(*a*) Nature of surroundings.	Field, pasture, lawn, clearing (how long cleared).		
(*b*) Nature of soil cover.	Weeds, brush, sod		
III. Description of trees:			
1. Species	White oak	White oak	White oak.
2. Number	I.	II.	
3. Special position (if not covered sufficiently by general description).			
4. Origin of tree	Natural seeding, sprout from stump, artificial planting, unknown.	Sprout	
5. Diameter (breast high).			
6. Height of stump			
7. Length of felled tree			
8. Total height			
9. Height to first limb			
10. Age (annual rings on stump).			
11. Time when cut, and after treatment			

(b) Description of test material and results of physical examination.

Notation as to station, site, and tree	A. a. I.	A. b. II.	B.
Number of test piece	1.	3.	
Exposure in tree	North.	Southwest.	
Height in tree	"Butt cut."	"Butt cut."	
Position in tree (with reference to periphery)	Not known.	Not known.	
Size of test material:			
Length	4	4	
Breadth	1⅝ inch.	1⅝ inch.	
Depth (measured across rings)	1⅝ inch.	1⅝ inch.	
Number of rings			
Width of rings (average)	2.7 millimeters.	1.5 millimeters.	
Summer wood as a whole	80 per cent.	54 per cent.	
Firm bast tissue	60 per cent.	37.5 per cent.	
Space lost by large vessels	14.7 per cent.	24.9 per cent.	
Moisture conditions when tested	Nearlyseasoned.	Half seasoned.	
Density	.84	.77	

(c) Results of tests made in Washington University Laboratory, St. Louis, Missouri, by Prof. J. B. Johnson.

Test piece.		Bending and crossbreaking. Size of test piece 1⅝ by 1⅝ by 24.						Compression.				Shearing.	
		Stiffness.		Ultimate strength.		Resistance to shock.		Endwise.		Transverse.		Longitudinal.	
Where procured.	No.	Range No.	*Modulus of elasticity, pounds per square inch.	Range No.	Modulus $\frac{3. W. L.}{2. b. h^2}$ pounds per square inch.	Range No.	Modulus inch-pounds per cubic inch.	Range No.	Modulus pounds per square inch. Size 1⅝ by 5 inches.	Range No.	Modulus pounds per square inch.	Range No.	Modulus pounds per square inch.
A. a. I	1	9	990,000	3	13,760	4	59	6	6,160	1	3,400	3	1,375
	2	5	1,280,000	1	18,500	1	92	7	5,480	3	3,100	1	1,560
Average	....	**3**	1,135,000	**1**	16,130	**1**	76	**3**	5,820	**1**	3,250	**1**	1,468
A. b. II	3	6	1,120,000	8	12,300	6	47	11	4,740	7	2,500	6	....
	4	10	920,000	5	12,700	5	55	9	4,980	4	2,800	7	1,225
Average	....	**4**	1,020,000	**3**	12,500	**3**	51	**5**	4,860	**2**	2,650	**3**	1,225
	5	11	850,000	9	11,400	2	83	8	5,230	5	2,700	4	1,375
	6	7	1,140,000	7	12,300	7	45	10	4,820	8	2,500	2	1,540
Average	....	**5**	995,000	**5**	11,850	**2**	64	**4**	5,025	**3**	2,600	**2**	1,458
B.........		Size: 1⅝ by 1⅝ by 18 inches.							Size: 1⅝ cube.				
	7	3	1,570,000	6	12,380	9	27	4	6,800	11	2,000	10	860
	8	8	1,100,000	2	14,690	3	82	1	7,800	2	3,200	5	1,260
	9	4	1,385,000	11	11,240	11	19	5	6,800	9	2,300	11	825
Average	....	**2**	1,351,667	**2**	12,770	**4**	43	**2**	7,133	**4**	2,500	**5**	982
	10	1	1,653,000	4	13,030	8	30	3	6,900	6	2,600	8	1,050
	11	2	1,581,000	10	11,590	10	22	2	7,700	10	2,100	9	940
Average	...	**1**	1,617,000	**4**	12,310	**5**	26	**1**	7,300	**5**	2,350	**4**	995

*Young's modulus of elasticity: $E = \frac{W. L.^3}{4 D. b. h.^3}$ where $\begin{cases} W. = \text{total load at center in pounds.} \\ L. = \text{length in inches.} \\ D. = \text{deflection in inches.} \\ b. = \text{breadth in inches.} \\ h. = \text{height in inches.} \end{cases}$

As stated before, these tests can hardly settle definitely any question. Samples 1 and 2 being selected stock, second growth, can not be used for comparison with samples of B, except to show that for stiffness the unselected southern stock is superior to the best northern growth, as also in resistance to endwise compression. The samples 3, 4, 5, and 6 are probably more nearly comparable to samples of B, and here we find the southern oak very much superior, not only in stiffness and columnar strength, but also in ultimate crossbreaking strength, while for resistance to shock at least one sample of southern oak is superior to three samples of forest-grown northern, and even to one of the best northern second growth. This piece (No. 8) exhibits, altogether, qualities which render the verdict tenable that southern oak is not necessarily inferior to northern oak in any of its qualities.

Beyond this it would not be safe to use these figures for generalizations. From Mr. Roth's examination of the two northern oak samples we learn that the time taken to lay on the same amount of

wood which the open-grown upland oak made in one year was, in the forest-grown lowland oak, 21.5 months, showing the former superior from the forest economical point of view as it is also from the wood consumers' standpoint.

Comparing these two sticks with reference to density they would stand as 5 to 4, while comparing the relative amounts of firm bast and spring wood the ratio would be 8 to 5; and Mr. Roth argues that the former ratio would probably give more nearly a comparison for strength and stiffness, while the latter should be considered as the proper ratio regarding the value of the two sticks for wagon spokes. In reality the tests for stiffness, if the modulus of elasticity is considered to indicate stiffness, proved the ratio to be nearer 6 to 7, the first stick showing least stiffness. The tests for cross-breaking strength establish a ratio of 6 to 5, while the ratio of resistance to endwise compression corresponds to the density ratio.

Resilience (resistance to shock), which Professor Johnson takes as the nearest expression of the quality called toughness, showed the ratio of 6 to 5. From these single tests we do not, therefore, derive an unmistakable relation of physical and mechanical properties.

FORESTRY INTEREST IN THE STATES.

While it may not be possible to point to any particular development as a sign of progress in the forestry movement, the indications that greater interest is felt throughout the country in the endeavors of the friends of forestry reform have become more frequent with every year. One of the most promising signs is the frequent discussion of forestry matters, not only in the general press, but especially in the papers devoted to the interests of the lumber business. These papers, as well as lumbermen at large, begin to recognize that the time is nearing when methods of obtaining the supplies for the lumber business must be modified so as to secure, instead of preventing, natural reforestation of the better kinds. How the present methods of lumbering reduce the chances of desirable natural reforestation will appear further on.

There are now holders of large timber areas who would be willing to follow a rational policy in regard to their lumbering operations if they knew how to do it. Since conditions vary so greatly, it would be impossible to give information in this respect capable of general application. On the other hand the presentation of what is involved in forest management, in a definite, concrete case, may aid in forming some idea of the manner in which other conditions may be satisfied.

I am fortunately able to furnish such reference to a definite case of proposed forest management, which, in my estimation, marks a new era in the forestry movement. I refer to the purchase by the Adirondack League Club of a large area of virgin timber lands (some 93,000 acres) in the southwestern part of the Adirondacks, with the stated purpose of placing it under forest management. As a proof of the bona fide intention of the club, I may say that the direction of the forest policy of the club was confided to the present writer. I deem this move such an important one, and the opportunity of teaching forestry principles in their application to a definite object so welcome, that I ask leave to reproduce here such parts of my report to the executive committee of the club as may be of general interest

and helpful in inducing other proprietors of woodlands to apply as far as practicable similar principles.

To the Executive Committee of the Adirondack League Club, New York:

* * * * * * *

The club is to be congratulated on two things: first, on the laudable intention of practically applying for the first time in the United States forestry principles to the management of its woodlands, and, secondly, on the excellent opportunity for such application offered in its valuable property, combining as it does the three essential conditions which may render profitable forest management in the United States at the present time possible, namely, a sufficiently large and compactly situated area, a large amount of available and valuable material uninjured by fire or otherwise, and proximity to large centers of consumption, to which it can be made accessible.

THE PROPERTY.

You have been fortunate in securing in a tolerably compact body one of the best-wooded, absolutely virgin timber tracts of the Adirondack region, situated in the southwestern outskirts of the mountain region proper, within easy reach of Albany and New York, the largest lumber markets of the East, with waters—the headwaters of Black River and of the Mohawk (West Canada Creek)—capable of floating the soft woods, and with a topography which admits of easy grades for roads and railroads and presents no serious difficulties of any kind for carrying on lumber operations and forest management.

As far as examined the property represents a hill country, well watered, with gentle slopes and no elevations more than 500 or 600 feet above the mean altitude of about 2,000 feet above sea level. The soil is a sand of moderate depth, overlying the native rock, richly impregnated with the products of humification from the fallen foliage of centuries and then covered with "duff," resulting from the imperfect humification of the spruce needles. It is a soil which, when exposed and put into cultivation, soon shrinks and deteriorates, having no durability for agricultural use, but which, if kept carefully under forest cover, forms a most excellent basis for tree growth and forest management.

The forest consists principally of birch* and maples† of magnificent proportions, with the admixture of beech and black spruce.‡ There occur on the tract also, although rarely in large numbers, except in a few localities, white pine, balsam fir, tamarack, hemlock (the latter sometimes of large size and in predominant quantity), and hard woods, single trees of black cherry, elm, and in low places black ash. None of these or of the few other species found need to be at present considered in the forest management, which will have to concern itself primarily with the birch, maple, and spruce. The ratio in which these kinds occur may be roughly estimated as averaging 40 per cent for the birch, 30 per cent for the maple (hard maple predominating) and beech, and 25 per cent for spruce, leaving, say, 5 per cent for the other timbers.

* * * * * * *

The beech, although, numerically equal to the maples, shows an inferior development and small diameter, and is for that reason hardly to be counted among the principal growth. It may, in fact, become rather troublesome in the forest management, owing to its superior capacity for reproduction under the prevailing light conditions, thus excluding the more desirable kinds.

The quantities of merchantable timber per acre it would, of course, be impossible to state from such a superficial inspection as was afforded the writer. But, from what could be seen in a four days' tramp through the woods, I should be inclined to consider an average yield of 6,000 feet of spruce (above 12 inches) and enough of birch and maple to make all together 15,000 to 20,000 feet of merchantable timber per acre a fair estimate. This refers, of course, only to the fully matured timber. There is also a large amount of "down timber," fallen trees, of which the sapwood only is defective, and which will increase the yield considerably.

As is the rule in a virgin forest, trees of all sizes and ages occur side by side. It is, however, noticeable that really young growth occurs very rarely, owing to the fact that the old growth has very dense and shady crowns, shutting out the light

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* Two species: *Betula lenta*, the black or cherry birch, and *B. lutea*, the gray or yellow birch.

† *Acer saccharum*, the hard or sugar maple, and the two soft maples *A. saccharinum* and *rubrum*.

‡ *Picea mariana*, formerly called *nigra*.

so essential to a proper development of the young plant. The apparently young growth of spruce especially, which is found here and there through the woods, is in fact nothing more, in most cases, than stunted growth of considerable age, which has been capable of persisting and vegetating under adverse light conditions.

To get at an approximate valuation of the property as a wood-producer the following calculation might be ventured: Allowing of the total area say, in round figures, 70,000 acres as fully productive, and taking 15,000 feet of merchantable timber standing per acre, I estimate the stock available, at present figures, as 1,050,000 M feet, board measure, worth on the stump, at present minimum price, a round million dollars. Allowing a rotation of one hundred years as desirable in which to cut over and reproduce this area—a shorter rotation would probably be quite practicable—the annual cut in the old stock would yield 10,500 M feet. To this must be added an accretion of 350 feet per year to the acre, an exceedingly conservative estimate, representing over the entire area 24,500 M feet of annual growth, so that the property would be capable of yielding annually for the next one hundred years, and practically forever, at least 35,000 M feet of lumber, which, figured at the present minimum price on the stump, means an annual income of $35,000.

* * * * * * *

It should, of course, be understood that an annual cut exceeding the above figure is by no means objectionable as long as old stock is on hand and due regard is given to reproduction. An annual cut of the same amount in material, or in value only, from year to year, presupposes that it is desirable to have a regular dividend of nearly even amount instead of irregular ones. If need be and if the conditions of the market make it appear more profitable, there can be no objection to increasing the cut, reducing it proportionately afterwards.

THE CONTRACT.

The club acquired its property with an undesirable liability upon it which is bound more or less to handicap its endeavors in the introduction of forest management. I refer to the contract under which a certain lumber firm obtained the right to cut during the next fifteen years all the spruce above 12 inches in diameter on any part of the property without any restrictions. While as a matter of financial expediency this contract may have been desirable, it was, I understand, an unavoidable condition in the purchase. As a matter of forest policy, the club can not flatter itself on having inaugurated any advance upon methods already existing. Aside from the facts that this contract confers a most valuable privilege at an exceedingly low figure and takes out of the hands of the club the unrestricted control of the property, from a technical point of view it can not be considered good forestry. Lumbermen in various parts of the country have before this abstained from taking all the cream at once, mainly because it did not pay, and, having left certain sizes of certain timbers uncut, have found and cut a "second crop" after a number of years, the smaller sizes having grown to fair dimensions.

Friends of forest preservation in their recommendations, and the commissioners of Crown lands in Canada in practice have made the size down to which timber might be cut a condition of forest conservancy. It can not be denied that by restricting the cut to special timbers and sizes presumably absolute clearing is avoided and the absolute exhaustion of the particular kinds of timber on the area prevented or at least delayed, and in so far as these two contingencies are attained there is a benefit in this restricted utilization. But these contingencies are matters of chance rather than of certainty, and the main object of forest management, namely, reproduction of the valuable timbers, is to a large extent, if not entirely, overlooked and frustrated. For, as I shall presently show, by culling out, as is done under your contract, the best of the spruce, this species is at once placed at a disadvantage as against those left on the ground. It is questionable whether any openings made in this culling process would seed themselves to spruce rather than to the prolific birch and maples, and even if a young growth of spruce should sprout up, would it find suitable light conditions to maintain itself? I repeat again that most of the spruce growth remaining after cutting would be not young growth, but stunted trees, which had been vegetating in the shade of the older timber.

A restriction in the number of trees per acre which might be cut or which might be left would have more show of rational conservancy, but even so the demands of a proper forest management would not be satisfied.

If it is considered desirable, as it decidedly should be, to foster and reproduce the spruce growth, it will be necessary to cut and utilize a part of the hard woods simultaneously—possibly before the spruce is cut—and the time and manner of cutting either will determine the manner of reproduction. The cutting must be done with a view to favor reproduction, and not in the haphazard way in which the lumberman does it. Here comes in the science of forestry.

A LESSON IN FORESTRY.

* * * * * * *

That forestry is a business carried on for profit seems still to be a matter unknown to many who talk and write on the subject. As agriculture is practiced for the purpose of producing food crops, so forestry is concerned in the production of valuable wood crops, both attempting to create values from the soil. Other conditions, like the preservation of climatic, soil, or favorable water conditions, which are claimed for the forest cover, may influence and *modify the manner* in which the primary object of forestry, namely, production of wood crops and profits, is attained, but they do not necessarily exclude this primary object. In fact, the demands of forest preservation on the mountains and the methods of forest management for profit in such localities are more or less harmonious; thus, the absolute clearing of the forest on steep hillsides, which is apt to lead to desiccation and washing of the soil, is equally detrimental to a profitable forest management, necessitating as it does replanting under difficulties.

Forest preservation does not, as seems to be imagined by many, exclude proper forest utilization, but on the contrary may well go hand in hand. Forestry in a wooded country means utilization of the wood crop in such a manner that it will reproduce itself in the same, if not in a superior composition of kinds, as the original growth. Reproduction, then, is the aim of the forest manager, and the difference between the exploitations by the lumberman and by the forester consists simply in this, that the forester cuts his trees with a view of securing desirable reproduction, while the lumberman cuts them without this view, or at least without the knowledge as to how this reproduction can be secured and directed at will.

The efficient forest manager requires no other tool than the ax or saw; he has missed his highest aim when it becomes necessary to use the planting tools, unless, indeed, he meant to introduce new species, which were not at all or not in sufficient number to be found in the original growth, or unless clearing and subsequent replanting appear the more profitable and more successful method of reproduction. In hilly and mountainous country this latter method is for various reasons not desirable; hence management for natural reproduction by proper use of the ax should here form the rule.

How is this reproduction secured? To understand this it is necessary to realize that as in the animal world so in the vegetable there is a constant struggle for existence and supremacy going on among the different species as well as among the individuals of the same species. All struggle for the occupancy of the soil. The weapons with which this struggle is carried on are various, offensive and defensive. This species seeks to gain foothold by prolific annual seed production, aided perhaps by the lightness of the seed, which is wafted by the winds for miles in all directions; the ubiquitousness of the aspen whenever an open space affords light is accounted for by this capacity.

Another species by its dense foliage shades the ground so that no rival can find favorable conditions of existence underneath; such are firs and spruces. Others again maintain themselves by developing a vigorous root system, which enables them to endure the shade of the superior growth, vegetating poorly, but biding their time until other agencies have decimated the enemy, ready then to occupy the field. The oak is an example of this kind. The alternation in forest growth, so often looked upon as a mystery, is thus accounted for. Man by fire or ax, nature by tempests and insect pests, removing the superior growth, the species which persisted under the shade of the former and escaped or resisted the destructive agencies will occupy the ground.

Especially the different requirements in regard to light conditions and relative rate of height growth, by which the species may or may not escape suppression by its neighbors, influence the temporary local distribution of plants and are of greatest interest to the forest manager. Light is one of the essential factors of tree growth and almost the only one which man can regulate. Forest management, then, could almost be defined as management of light conditions. The leaves exercise their functions under the influence of light and feed the tree by assimilating the carbon of the air. Such thinly foliaged trees as the aspen and some of the birches and others can only exist under a full complement of sunlight; they are therefore endowed with a rapid rate of height growth to enable them to grow quickly out of the danger of being overshadowed by their neighbors. Other species, like the firs, and in less degree the spruces, with a dense foliage and a large number of leaves, can be satisfied with less light and are as a rule slower growers; other kinds again, like the oak, while dependent for their full development on a large amount of light, probably by virtue of specially vigorous root action, can persist in the shade for a long time until more favorable light conditions allow thrifty growth. Especially

are the young seedlings of most kinds very sensitive in regard to light conditions and some have such a small range of light and shade endurance that, while there may be millions of little seedlings sprouted, they will all perish, if some of the mother trees are not removed and more light given ; and they will perish equally if the old growth is removed at once and the delicate leaf structure under the influence of the direct sunlight and heat is called upon to exercise its functions beyond its powers.

We can, then, understand that not only the different species, but the same species at different periods of life, make varying demands in regard to light conditions ; and the art of the forest-manager in securing reproduction as well as in other operations, thinnings, etc., consists mainly in a proper regulation of light conditions by a proper and timely use of the ax.

The composition of the forest, climatic, soil, and moisture conditions modify again the requirements, so that all general rules of management need to be modified according to local conditions ; and it will appear at once that a considerable exercise of judgment born of experience and knowledge is expected of the forest manager.

To further elucidate these and some other considerations involved in forest management, let me briefly trace the manipulations with reference to a specific case, in the reproduction, for instance, of the beech, as practiced over large areas in Germany. The beech, like many other timbers, bears seeds only periodically. Seed years occur in different localities at periods varying from three to even twenty years, records of their occurrence being kept. A few years before the seed year is expected to occur the forest is somewhat thinned out to admit air and light upon the soil, in order that the litter of the forest floor be more rapidly decomposed and humified and so may form a suitable seed bed for the sprouting of the seed and also to stimulate the mother trees to a plentiful production of superior seed. In this thinning the inferior material and the undesirable kinds are first removed and such kinds as reproduce themselves easily without aid from the forester. When the nuts fall pigs may be driven into the woods to plow them under. Under favorable conditions a soft green carpet of young beech seedlings will be found to cover the ground in the spring next after the seed year.

Now comes the critical period. If the mother trees were left the whole crop would be lost, and while waiting for the next seed crop under the altered light conditions, which invite grasses, weeds, and other species to come in, the difficulties in securing reproduction are increased. By thinning out gradually, the proper amount of light is given to the young crop and when in three or four years the last of the mother or nurse trees are removed, a thicket of young beeches has replaced the old growth. In a similar manner, with necessary modifications in procedure according to species, climate, and soil, is the natural reproduction of other species effected.

The practice of the forest-manager, then, is to assist the desirable species in the struggle for existence and supremacy, to antagonize the undesirable ones, and to create proper conditions of soil, light, and composition of species for a desirable reproduction.*

The practice of thinning is based on similar principles. Regard to the danger of windfalls, of fire, of frost to the young plants, etc., will also influence the management.

So much for the technical part of forest management.

There is, as in every producing business, besides the technical part, a financial or mercantile part of the business. So in forest management we find a technique, which is based upon a thorough knowledge of natural sciences, and a mercantile part, which requires a knowledge of the factors that make such a business profitable. The technical administration and the mercantile administration must work together harmoniously, adjust and compromise their needs in order to arrive at results desirable to both.

The conditions of a proper mercantile forest management need also a brief consideration here. The absence of forest management in the United States is due to various causes, mainly arising from the state of our cultural and material development. As long as the competition of wood supplies from virgin lands, exploited for the best timber only, is to be met, forest management will be beset with great difficulties from a financial point of view. Yet it is not impossible, impracticable, untimely, or unprofitable in the location and under the conditions in which the club's property is found. A near market and facility for bringing even inferior ma-

*Reproduction from seed only is here considered. The reproduction from the stump, of which broad-leaved trees—not the conifers—are capable, may be left out of consideration at present ; its desirability or undesirability on the property may be discussed at some other time.

terial to market profitably are the conditions without which forestry is financially impracticable. Accessibility, easy cheap, and permanent means of transportation furnish the keynote of profitable forest management.

The lumberman places only a temporary value on his property, quickly gets out the most valuable timber, taking the cream and leaving the balance, like skimmed milk, in the woods, to rot, burn, deteriorate. If nature so wills it and some cream was left in the first operation, he may return and repeat the skimming process once or twice, leaving at last an undesirable scrub-growth or "bush." The forester considers his property as a permanent investment, to produce revenue constantly and forever, in increasing rather than decreasing ratio. The factor of permanence is ever present in his methods. Like the owner of a large office building, he spends part of his income from year to year to repair, improve, and enhance its value.

Here again, as in the technique, the business of the lumberman differs in methods of administration from that of the forester. The lumberman works for the present, the forester for the future. The lumberman begins his operations wherever he can get out his timber most readily; the forester has different reasons for cutting over the district in a certain order (danger from windfall, frost, fire, insects, etc.). The lumberman builds shanties, temporary roads, and water ways; the forester builds houses or at least plans for permanent occupancy, and he plans, lays out, and builds permanent roads and other permanent means of transportation, which will enable him to utilize to the fullest extent all the product of the soil, from whatever part of his property it may appear desirable. The difficulty of doing so profitably, often, to be sure, hampers the technical management. The technical manager might see the desirability of thinning a young growth in order to bring it to a more rapid development, but not being able to dispose of the inferior material, the financial manager objects to the expenditure for the operation. The technical manager can see that in order to secure desirable reproduction, some kinds of timber should be cut first and others later, but there being no means for marketing the former, and the latter being, perhaps, floatable by the natural water ways, the financial manager insists that these be utilized first, and thus the task of the technical manager may be greatly aggravated.

The demands of both technical and financial considerations constantly require adjustment. Protection of the forest against fire is a constant care both of the technical and financial manager. How to do this effectively and how to do it with the least expense is the problem. Here again a proper road system and redistricting of the area is an important factor, enabling the manager and his force to reach easily any part of the property that might be endangered, and secondly enabling the utilization of inferior material, which, if left in the woods, increases the danger from fire.

As the aims of the technical part of forest management can be summed up in two words—natural reproduction—so can the financial policy be formulated as consisting in wise curtailment of present revenues to secure permanent and increasing revenues for the future.

* * * * * * *

For the purpose of illustrating the financial working of a forest administration, I may subjoin the following table, which exhibits the actual results of the forest administration of the Duke of Anhalt in Germany for eight years. The property consists of somewhat over 57,000 acres in all; mountainous and mostly of coniferous growth, presumably without much surplus old stock and, if the annual cut of 47 cubic feet of wood per acre—a very low average—represents the annual accretion, not of very good production. The annual cut averages in round numbers 2,675,000 cubic feet, of which 27 per cent represents lumber wood, the balance firewood; or, in round numbers, 7,000,000 feet board measure and 20,000 cords firewood. The administration is of old standing, and expenditures may be considered as current and not extraordinary; receipts other than wood refer probably to rent for meadowlands, game, and fishing privileges, stones, etc. The administration cuts, but does not move the wood; prices, therefore, refer to the cut wood in the forest. Besides one forest director with three assistants and several clerks, there are fifteen district officers and forty-eight assistants and guards, the cost of the administration amounting to $30,000 annually.

Results of forest administration of the Duke of Anhalt for eight years.

[Round numbers.]

Years.	Receipts.						Expenditures.					Net profit.	
	For wood				Other.	Total.	Wood cutting.	Roads.	Planting and other improvements.	Sundries.	Total.	Total.	Per acre.
	Total.	Per cubic foot, solid.											
		Timber.	Cordwood.	All together.									
1881	141,400	8.6	2.7	5.2	25,300	166,700	23,000	3,110	9,120	6,440	69,700	97,000	1.63
1882	137,000	8.4	2.8	5.2	28,200	165,200	21,000	2,450	9,650	5,470	67,400	97,900	1.65
1883	150,400	7.4	3.	6.	26,850	177,250	20,000	2,920	8,960	6,050	67,000	110 000	1.83
1884	153,260	8.9	2.7	5.9	26,800	180,060	20,900	2,590	9,900	5,800	68,350	111,800	1.88
1885	147,200	8.3	2.6	5.6	25,600	172,800	20,700	2,550	10,800	6,220	69,200	103,600	1.74
1886	152,500	7.9	2.4	5.3	26,750	179,250	23,950	2,630	10,000	6,570	72,200	107,170	1.79
1887	155,360	8.5	2.5	5.8	25,840	181,200	21,570	2,940	9,96	6,200	69,800	111,360	1.85
1888	161,150	9.4	2.6	5.9	25,000	186,150	22,800	3,100	9,830	7,470	74,700	111,400	1.82
Yearly average	149,780	8.5	2.7	5.6	26,290	176,000	21,740	2,786	9,660	6,275	69,700	106,300	1.78

Proportion of expenditures to gross receipts.

	Per cent.	Cents.
Wood cutting:		
Per cent of gross receipts	12.4	
Per cubic foot, solid		75
Roads:		
Per cent of gross receipts	1.6	
Per cubic foot, solid		4.8
Planting and other improvements:		
Per cent of gross receipts	5.5	
Per acre		16.2
Sundries	3.6	
Total	40	
Net profit—total	60	

From lumber wood alone the average income would be $59,500 in the woods, the cost of cutting in round numbers $5,500, leaving net income of $54,000, or over one-half of the total net profit.

FOREST POLICY.

The policy of the club will have to be to find, as soon as possible, means of marketing the hard woods. This involves laying out and gradually constructing a rationally disposed, well built, permanent system of roads, the encouraging of railroad building to or through the tract, and of manufactures near to it which can utilize the inferior material. Of the latter may be mentioned pulp mills, employing both mechanical and chemical processes (the former for utilizing the hard woods, especially the beech and inferior birch), small woodenware, furniture, and carriage material manufactures, etc.

There are quite a large number of "seamy" spruce trees on the land, unfit for lumber, which would make most excellent pulp material, in addition to the top material alluded to further on.

Especially desirable is the establishment of enterprises using firewood or charcoal. The club could afford to give the wood leave for smaller-sized cord wood for almost nothing, while with cheap fuel and convenient means of transportation the manufacturer may be able to shoulder the inconvenience of using inferior material and of less convenient location.

I desire here especially to call attention to the great importance which the manu-

facture of pulp has acquired during the last few years. It may prove one of the most potent enemies to our forests, or else it may become the best friend of those who strive to introduce rational forest management, according to the manner in which the raw material is obtained. By using up the inferior material it may supply the one condition of profitable forest management.

Since by the present processes of manufacture the hard woods can only be used as filling material of the pulp made from coniferous woods, it should be studied how both kinds may be utilized simultaneously, in order to aid instead of impede the task of the forest manager in securing reproduction. I advise especially that you do not precipitately contract away the soft pulp woods without reference to the simultaneous utilization of the hard woods.

It may not, perhaps, be necessary for the club to do its own lumbering; this may be done under leases to lumbermen, as in the case of the spruce. In that case, however, the leases must be so formulated and executed that the object of the forest manager—proper reproduction and improvement of the property—can be attained at the same time.

To avoid complications and to make the forest management most effective, it would, however, be altogether preferable that the cutting be done on account of the club, the lumbermen to buy the logs or cord wood cut, as it would be irksome and difficult to control the lumberman in his operations. This method of doing would have also the advantage that the men engaged in cutting and superintending the logging are under directions and may partly enlarge the permanent force of the forest administration.

The working for reproduction must be mainly directed upon the birch, maple, and spruce, except where special soil conditions and composition of the original growth demand or permit the favoring of other timbers. The detail in methods will have to be a study for the resident manager, a problem which can not be solved *ex cathedra*, but needs careful observation and consideration, and perhaps some trials first.

That the property must be guarded against fire, trespass, and improper cutting under the contract goes without saying. The cutting open of the boundary lines and proper marking of the same, with subsequent frequent revision or renewing of the marks and the districting of the property, should naturally receive early attention, as protection is facilitated by a definite knowledge of the extent and nature of the property to be protected.

FOREST FIRES.

The greatest danger against which the club has to guard is that from fire. It is miraculous almost that fire should not before have touched this tract, and this can be explained only by the comparative isolation in which the tract has been hitherto. With the opening up of the property and especially with the beginning of lumber operations, the danger increases, and hence this great enemy of the forest must be anticipated.

The elaboration of regulations in regard to the use of fire on your property should engage your earliest and earnest attention. In spite of all rules and regulations and precautions against fire, it is to be expected that fires will break out, and preparations to fight the fires effectually will also have to be in the programme of your administration. I can not too strongly urge upon your committee the necessity of dealing with this subject energetically and unflinchingly at the outset. The whole fire question in the United States is one of bad habits and loose morals. There is no other reason or necessity for these frequent and recurring conflagrations. It requires only that a strong moral impression be made upon those responsible for them to reduce and ultimately remove this bugbear of American forests.

The club can afford to employ its entire income for several years solely to this object of showing its determination to break the spell and to make the appearance of fire the exception and not the rule. This can be done only by a comparatively large and well-organized force of fire guards, who will enforce the proper preventive measures and regulations rigidly and put out any fires as soon as discovered. By as much as the property is made accessible through a proper road system and convenient division into districts, by so much will the number of necessary guards and their labor be diminished.

The danger and damage from fire is increased wherever lumbering is carried on, especially from the fact that the leavings, tops of trees, and limbs dry rapidly and lend intensity to any running fire. The proper disposal of these leavings should have been considered in your lumber contracts. In the absence of conditions to that effect the club must dispose of the matter on its own account. It has been urged that the leavings should be gathered and burned. This is expensive and

wasteful and it is my opinion that, at least with the spruce under the conditions before us, it is unnecessary. The danger arises from the fact that the tops braced up by the branches from the soil are dried and kept dry, like tinder. By lopping the branches and letting both branches and tops fall to the ground, it is to be anticipated that the material would be kept wet from the winter snows and soon be rooted. Besides some useful material for pulp manufacture, which the lumberman would have left, might be saved from this top material. I would at least recommend the trial of this method. The lopping should be done soon after the felling and it might be possible to make arrangements for this work with the contractor for the lumber.

* * * * * * *

ORGANIZATION.

It would be folly to undertake for the present the more refined methods of forest management practiced in Europe, or to attempt an elaborate system of organization, such as may in time become desirable. Yet, even if it were only for the purpose of properly guarding the interest of the club and its property, an organized administration must appear desirable. Such an administration would require a resident manager, three or four district officers, and a large number of permanent or temporary guards. The manager should, if possible, be a man with the knowledge of the principles of forest management as practiced abroad, yet also acquainted with the difference of conditions and methods prevailing in the United States, and, while determined and energetic, yet possessing a sufficient amount of that tact which is required to introduce new methods without unnecessarily creating antagonism and ill-will. His duties would be to have the general charge of the local administration, executing the orders of your committee, assisting the members of the club is locating and constructing their camps. He will have to study, map himself in detail, and district the property and lay out the road system, supervise the construction of roads and other improvements. He should therefore be conversant with such surveying and engineering work. He will superintend the execution of the lumber cutting, make out the lumber inspector's statements for settlement, and after having familiarized himself with the prevailing forest conditions, devise in detail the plans for a proper forest management. He will be responsible for the protection of the property against fire, theft, poaching, etc., keep the force under him to its duties and attend to prosecutions of offenders in the local courts, etc. It may be difficult, though not impossible, to find a competent man of such quality and knowledge. The success of the club's enterprise must largely depend upon finding that man. I have described here only a part of the duties which are expected of the district officers in French and German forest administrations. To such a man the club can afford to pay a good salary.

The district officers should be reliable men, with some knowledge of woodcraft, and capable of acting on their own responsibility. They should be stationed each one in a different district, for which he will be held responsible. During the lumbering season they will be mainly engaged in watching the lumber operations and surveying lumber cut under contract or otherwise. Those not so engaged will assist the manager in the survey and locating of roads, etc., or they will superintend directly the work on roads, improvements, or other operations. In summer time and during the hunting and fishing season they will be especially charged, with the aid of the guards, to watch for fires and trespassers, and their energies should be entirely devoted to the duty of protection.

The permanent force of guards need not be large, only as many as could be profitably employed in the works of improvement going on during the off season, when danger from fire or poaching is passed. One assistant to each of the three or four district officers and to the manager might suffice. These officers as well as the guards must be under the direct orders of the local manager.

I have pointed out that this permanent force could be larger, if the club does its own timber cutting, the foremen of the lumber camp becoming guards during the hunting season. Otherwise this force may have to be increased temporarily during the time of need, say for the months of June and October. But the protective efficiency could be greatly enhanced without much, if any, additional cost by having only licensed guides on the property and by charging these guides, who are necessarily all the time going through the woods, with the right and duty to enforce the regulations of fire and game laws.

In order to make this force still further effective, all the officers and guides should be clothed, if that be attainable, with sheriff's power for the enforcement of the State game, fire, and trespass laws. It is the present circumlocutory manner of applying the law and absence of proper police force which make the State laws largely nugatory. Responsible people, with a permanent interest in the property they are to

guard, clothed with the power to apprehend and bring to jail any offenders, will soon make that moral impression which is necessary to change present malpractices.

The permanent officers should live on tho property and be so located as to guard especially the entrances to it most effectively. The cost of an efficient service like the one described I estimate in round figures at $8,000 for the permanent force, the lodges for officers to be furnished by the club. For the first few years as liberal a curtailment of the income as possible should be suffered by the club for improvements, especially roads. The value of the property will rise in excessive proportion to the expenditures made in rendering it accessible.

* * * * * * *

In fact, as soon as the service is satisfactorily organized and the preliminary work of mapping and the location of a rational road system determined upon, the work of developing it should be pursued with all energy up to a certain point, afterward more gradually; for, as I have tried to impress upon you in the foregoing, proper and profitable forest management is dependent upon the possibility of marketing inferior material, and this is possible only with permanent and easy means of transportation.

* * * * * * *

I have dwelt at length on some elementary considerations, because with the present movement in the State of New York to establish in the Adirondack region an extensive State park it is desirable that the members of your club should be fully imbued with proper conceptions as to what is or ought to be involved in such a proposition. The State of New York has hitherto been incapable of grappling with the question of forest preservation in the Adirondacks solely because of ignorance as to what forestry and forest conservation involve, and, secondly, because the question was not treated as a business proposition. The club will fail in the same way, as far as forest management and forest conservation are concerned, unless it is placed upon a business basis.

The great State of New York, with 3,000,000 or 4,000,000 acres of woodlands reserved as a State park as proposed, ought to be able with such a park not only to protect its watersheds and to furnish hunting, fishing, and health resorts to its citizens, rich and poor, but with only half the area productive and large amounts spent for improvements and recuperation of burnt areas such a forest property should not only pay its maintenance expenses and interest on purchase money, but by and by return to the treasury and relieve of taxation its citizens to the amount of several million dollars.

FORESTRY EDUCATION.

The difficulty of introducing proper forest management into the United States, aside from that inherent in the economic development of the country in general, as pointed out in the foregoing pages, may be assigned to the absence of competent managers. The demand for such will presently arise, and it will be difficult to meet it. It is questionable whether forestry can be studied in this country to advantage as long as it is nowhere practiced, and hence practical illustration is lacking. On the other hand it is doubtful whether foresters can be imported from abroad capable of adjusting their methods to the different conditions existing in this country. It seems best, therefore, that young men with suitable preliminary preparation should go abroad to acquaint themselves, partly at the forest academies and partly by practical work in the woods, with the theory and practice of forest management. A sojourn of from one to two years abroad should suffice for anyone equipped with the necessary botanical and technical preparatory education.

For the purpose of ascertaining the present educational facilities existing in this country, letters of inquiry have been addressed to the various agricultural colleges and experiment stations. Leaving out negative replies, the following abstracts from letters received from professors of horticulture and botany show the extent of these facilities.

Students coming from these courses and wishing to prepare themselves to become forest managers, may find it advantageous, before

taking a course abroad, to avail themselves of the facilities of this Division, now quite considerable, for the purpose of acquainting themselves with the literature, classic and current, and with the theories upon which forest management is practiced abroad.

VERMONT.—*State Agricultural Experiment Station;* W. W. Cooke, director: Forestry is incidentally touched upon in our course on physiography. Special attention is given to influence on rainfall and climatology. All students in agricultural course take physiography (Tyndall's work) in spring term of freshman year.

RHODE ISLAND.—*State Agricultural School;* Prof. L. F. Kinney will teach forestry two hours a week in the spring term, and discuss in lectures the propagation of forest trees, methods of planting, effect of forests on climate, etc. All students take this course. Present class, 30.

MASSACHUSETTS.—*Agricultural College;* Prof. S. T. Maynard: Forestry taught twelve weeks in junior year by lectures and text-books. Thorough botanical study of American forest trees. In horticultural lectures propagation of fruit and ornamental trees, special methods in nursery, transplanting, and arranging in forest plantations, time of cutting timber, seasoning, etc.; quality of wood and timber of common timber trees, study of condition of forests, especially in New England, importance of their preservation, influence on climate, rainfall, droughts, etc. *Bussey Institution of Harvard University;* Prof. B. M. Watson: Give thirty-six lectures on trees and shrubs, in addition to regular course on horticultural practice, bearing chiefly on ornamental planting. Instruction on methods of propagating and planting, care of nurseries, and method of treatment to bring existing plantations into good condition and to maintain them so.

NEW YORK.—*Cornell University, College of Agriculture;* Prof. A. N. Prentiss: Lecture on arboriculture once a week during the year, with collateral reading and some field and laboratory work on native trees. Some lectures on forestry in Europe and on forestry and forest problems in the United States. Study wholly elective and attended by fourteen students.

PENNSYLVANIA.—*State College;* Prof. W. A. Buckhout: Lectures on forestry. Endeavors to present the subject in all its parts.

TEXAS.—*State Agricultural College, horticultural department;* Prof. S. A. Beach: Forestry is given under the senior year of the courses of agriculture and horticulture, during the fall term. Two recitations and one "practice" per week. Practice with compound microscope on structure of leaf and wood. Identification of trees. No strictly forestry course.

MICHIGAN.—*Agricultural College;* Prof. J. W. Beal: Forestry elective in senior year. Daily study twelve weeks. Lectures. Excursion to arboretum and woods. Study of the most prominent species of the neighborhood, physiology and growth, classification, something of distribution, management of forests here and in Europe. Timber, structure, and uses. About half the senior class, if any, elect forestry, say fifteen to twenty.

MINNESOTA.—*University, College of Agriculture;* Prof. S. B. Green: Give all instruction in winter, so can not demonstrate some points as I would like to do. Lectures, in connection with Hough's Elements of Forestry as text-book, and collection of plants on University grounds. Special attention to climatic effects of forests. Economic value, shelter belts, desirable species to plant, and methods of planting, identification of species. All graduates required to take the course and it is very popular.

MISSOURI.—*Agricultural College and Experiment Station;* Prof. J. W. Clark: Instruction by lectures and practical work in the nurseries. Use, durability, rapidity of growth, adaptation, modes of propagation and cultivation, diseases, insect enemies. About eight students take the course.

NORTH DAKOTA.—*Agricultural College;* College lately established. Catalogue shows contemplated lectures (six) on forestal subjects.

SOUTH DAKOTA.—*Agricultural College;* Prof. C. A. Keffer: Forestry taught by lectures and assigned reading. Students required to take field notes on characteristics, rates of growth, methods of culture, etc. Excursions to natural woodlands and plantations. Influence of forests on climate, wind-brakes, characteristics of trees suitable to South Dakota. All junior class take forestry. Ten students this year. Forty students worked on the forest plantation.

KANSAS.—*State Agricultural College;* Prof. E. A. Popenoe: Instruction in forestry given only so far as relates to propagation and management of trees for wind-brakes and ornamental planting. Instruction to all students of the second year. Plantation of 20 acres of forest trees on college grounds, set both in pure blocks and mixed. Thousands of trees experimentally propagated annually. This work and the care of plantations in the hands of students almost exclusively.

ILLINOIS.—*University of Illinois, College of Agriculture;* Prof. T. J. Burrill: Seven weeks optional instruction on forestry to senior class. Few, sometimes none, take it. In the regular course, forestry touched upon under botany and landscape gardening. Species identified in the woods and the laboratory, and characteristics studied, with some lectures on geographical distribution. Trees for ornament and shelter studied in ten lectures, with illustrations on the grounds. From ten to twenty students in this required course.

OREGON.—*Agricultural College, Experiment Station;* Prof. E. R. Lake: Forestry elective in fourth year. Institution only three years old. In second year students in the mechanical course have a course on "wood structure." Use Ward on "Timber and its Diseases," with lectures.

UTAH.—*Agricultural Experiment Station;* Prof. E. S. Richman: Nothing done yet. No class yet for second year. In the future I will make forestry a special feature, chiefly with reference to propagation and cultivation of trees valuable for lumber.

COLORADO.—*Agricultural College, Experiment Station;* Prof. C. S. Crandall: No special course in forestry, but in connection with horticulture; lectures on gathering, preservation, and sowing of forest-tree seeds, treatment of young seedlings, and best methods of culture, especially of species adapted to this region. Art of transplanting and use of trees for ornament, shelter belts, etc. Ten students in last class.

CALIFORNIA.—*University of California, Experiment Station;* E. W. Hilgard, director: Forestry taught only incidentally, as connected with the subject of economic botany.

STATISTICS OF EXPORTS AND IMPORTS OF WOOD AND WOOD PRODUCTS.

As has been customary hitherto the statistics of forests products as extracted from the report of the Bureau of Statistics is exhibited in the subjoined tables, in comparison with the figures returned for the year 1880, from which we learn that our exports have grown in value by about 75 per cent during that period, while imports have advanced only 50 per cent. It will be observed that the increase in exports is greatest in the crude material.

Exports of wood and wood, products, 1880 *and* 1890.

Articles.	1880.		1890.	
	Cubic feet.	Value.	Cubic feet.	Value.
Firewood	387,600	$11,552	978,944	$16,746
Boards, deals, and planks	23,767,000	4,223,259	51,067,833	9,974,888
Joints and scantling			2,223,666	381,640
Hoops and hoop poles	5,339,800	427,187	749,725	59,978
Laths	79,575	11,936	167,856	24,951
Palings, pickets, and bed slats			238,480	30,653
Shingles	760,354	165,893	511,378	111,926
Shooks:				
Box	544,328	136,082	474,228	118,557
Other	35,109,760	3,510,976	2,299,821	766,607
Staves and headings			37,152,855	2,476,857
All other lumber	6,379,590	765,550	11,292,842	1,355,141
Timber:				
Sawed	16,365,346	2,219,320	22,582,000	3,384,847
Hewed			8,732,761	1,381,747
Logs and other timber	9,874,100	789,927	21,004,325	1,680,346
Total unmanufactured	98,607,455	12,261,682	159,476,714	21,764,884
Manufactures of—				
Doors, sash, and blinds*	....	....	427,787	320,840
Moldings, trimmings, etc	....	....	155,060	116,295
Hogsheads and barrels, empty	349,372	262,029	567,037	425,278
Household furniture	2,205,171	1,653,878	4,118,506	3,088,902
Wooden ware	441,516	331,137	480,687	360,515
All other manufactures	2,304,867	1,728,650	2,930,420	2,197,815
Total manufactures	5,300,926	3,975,694	8,679,497	6,509,645

*Until 1884 the exports of doors, sash, blinds, moldings, etc., are included by the Bureau of Statistics in "all other manufactures," and can not be given separately. For the same reason the reports of some other articles can not be given separately for every year.

Exports of wood and wood products, 1880 *and* 1890—Continued.

Articles.	1880. Cubic feet.	1880. Value.	1890. Cubic feet.	1890. Value.
Naval stores:				
Rosin				$2,762,373
Tar	....	$2,452,908	....	56,105
Turpentine and pitch				35,037
Spirits of turpentine	....	2,132,154	....	4,590,931
Total naval stores and spirits of turpentine	....	4,585,062	....	7,444,446
Ashes	....	110,578	....	26,211
Bark and tanning extracts	....	210,126	....	263,754
Ginseng	....	533,042	....	605,233
Matches	39,749	119,246	20,761	62,284
Agricultural implements ......number	28,205	2,245,742	....	3,859,184
Sewing machines	65,975	1,649,367	111,751	2,793,780
Musical instruments	....	811,177	....	1,105,134
Carriages and steam and horse cars	....	1,407,425	....	4,746,678
Total miscellaneous	105,724	7,086,703	132,512	13,462,258
Total exports	104,014,105	27,909,141	168,288,723	49,181,233

Imports of wood and wood products, 1880 *and* 1890.

Articles	1880. Cubic feet.	1880. Value.	1890. Cubic feet.	1890. Value.
Free of duty.				
Wood, unmanufactured, not elsewhere specified:				
Firewood	13,182,816	$266,044	19,669,376	$320,882
Logs and round timber	4,373,400	349,872	11,812,775	945,022
Railroad ties	3,565,983	213,959	6,684,177	444,513
Shingle and stave bolts	1,057,025	84,562	1,360,687	108,855
Ship timber	172,980	43,245	363,724	90,931
Ship planking	107,691	35,897	104,991	34,997
Wood pulp	....	5,740	....	100,443
Hemlock bark	....	476,149	....	163,673
Dutiable.				
Wood, unmanufactured, not elsewhere specified	154,024	19,253	89,352	11,169
Timber	49,854	6,222	*84,960	10,620
Lumber:				
Boards, planks, deals, etc	39,542,864	4,763,441	48,344,000	6,724,716
Clapboards	727,333	19,759	1,636,000	75,672
Hubs, posts, lasts, and rough blocks	555,328	99,959	268,583	48,345
Laths	2,079,344	110,505	4,936,720	361,375
Pickets and palings	379,040	31,846	652,880	38,897
Shingles	823,788	116,608	2,728,894	414,921
Shooks and packing boxes	316,128	79,032	603,668	150,917
Staves	13,243	4,729	1,591,071	427,998
Bark extracts, chiefly hemlock	....	22,863	....	†481
Sumac	....	588,911	....	376,784
Cork and cork bark, unmanufactured	....	104,808	....	222,933
Matches	4,959	14,879	14,686	44,059
Manufactures:				
Casks and barrels		3,517		632
Cabinet ware and furniture		147,783		414,780
Osiers and willows, peeled and dried	1,209,945	21,833	1,909,381	27,646
Osier and willow baskets		142,214		372,356
All other manufactures		592,112		516,622
Free of duty.				
Cabinet woods:				
Box	....	27,563	....	36,712
Cedar	....	465,160	....	472,478
Ebony	....	84,354	....	47,794
Granadilla	....	5,050	....	2,322
Lancewood	....	14,655	....	8,993
Lignum-vitae	....	28,343	....	45,967
Mahogany	....	266,026	....	624,719
Rose	....	178,578	....	38,959
Sandal	....	3,400	....	102
All other cabinet woods	....	305,354	....	249,108
Cork wood or bark, unmanufactured	....	658,830	....	1,213,876
Total	68,520,349	10,403,044	94,845,925	15,291,269

*Quantity not all stated. †Hemlock only.

ARTIFICIAL RAINFALL.

By an amendment in the Senate the appropriations for this Division were increased by the sum of $2,000, and the words "for experiments in the production of rain" were added to the reading of work to be performed under the appropriations.

At first sight the reference to this Division of such experiments would appear to have been made by reason of the claimed influence of forest areas upon the distribution of rainfall. It was, however, learned that these experiments were not intended to have such a connection, nor were they to be devised for the purpose of finding out any special means for the production of rainfall, but they were to be carried on upon the assumption that explosions would have the desired effect, and the money was appropriated to be expended in the purchase of explosives and in their discharge.

With such a programme the reference was, to be sure, unfortunate, for aside from the fact that neither the Division nor the Department in any of its branches commands the means or the men to conduct such explosions or the instruments which should at least be observed during the explosions in order to arrive at an understanding of the results, should any be attained, the amount appropriated in the absence of such means and persons is so totally out of proportion to the needs of the experiment, and, indeed, to the expected overawing result of controlling nature's most potent and hidden forces, that an attempt to use it in the proposed manner could hardly fail to be barren of results.

On the other hand, the War Department commands cannon, explosives, and men trained and accustomed to handle them, and in its Signal Service, instruments for meteorological observations and observers, and as long as the experiments are to be carried on upon the assumption that explosives will be effective, I have submitted the propriety of asking the coöperation of the War Department in this matter. I have also submitted, as my opinion, that the assumption for such experiments is, to say the least, hazardous, and that a much better use of the money could be made and valuable results much more likely attained by devoting it to a series of experiments which would bring us first nearer to a conception of what forces are at work in producing rain and to learning more about the chances of substituting feeble human efforts for grand cosmical causes.

The theories in regard to the causes of storms, and especially their local and temporal distribution, are still incomplete and unsatisfactory. It can by no means be claimed that we know all the causes, much less their precise action in precipitating moisture. It would, therefore, be presumptuous to deny any possible effects of explosions; but so far as we now understand the forces and methods of nature in precipitating rain there seems to be no reasonable ground for the expectation that they will be effective. Hence, while I do not believe, contrary opinions of high authorities notwithstanding, that such experiments are necessarily devoid of merit, as long as they are conducted upon a careful, scientific plan and a large enough scale, it would be unreasonable and contrary to the spirit of our advanced civilization to rush into a trial which does not seem warranted by our present knowledge, instead of starting with a series of carefully devised experiments, the first object of which would be to learn something of the effects of explosions upon the atmosphere, a knowl-

edge which we do not possess, and which, if not leading to the power of controlling rainfall, may considerably advance our knowledge of meteorological forces.

It sounds quite simple to try whether explosions will produce the precipitation, but when it comes to practically arranging the trial, such questions as the following it seems must be settled first: What kind of explosive shall be used? Is it intensity or frequency of explosion that should be tried? What amount should be used? What means of exploding are best adapted to the purpose and in what manner should they be employed; how high above ground would the explosions be effective? Lastly, how shall we know whether precipitation was due to the explosions? How far did other conditions influence precipitation, etc.? These are questions which it would puzzle experts to answer on any basis of present knowledge.

A large number of trials, with all sorts of differences in the conditions, might possibly settle some questions, but, unless careful observations, not easily devised, were made simultaneously as to the effects upon primary conditions, under which the result is obtained, our trials would lead us no further than we are at present, namely, to the very unsatisfactory assumption upon which we based our trials.

Under these circumstances, up to the present writing no attempt has been made to advance this problem.

Meanwhile I have tried to trace the history and scan the evidence which has led to the assumption that explosions will produce precipitation, and incidentally I have also inquired into other means of artificial production of rain which have been proposed.

It is no wonder, in view of the important office which the absence or presence of rainfall plays in the economy of man, that the desire to control it is as old as history, and various attempts to do so have been made or proposed in all parts of the world. The resort to prayer for the purpose is well known. In India the rainmaker, called *Gapogari*, is an important personage, and similar professional rainmakers are found among African tribes and among the Indians. These, to be sure, have their secret methods, with which our knowledge of natural forces could hardly harmonize.

In more recent times two artificial causes of rainfall have exercised the minds of speculative meteorologists, fire and explosions.

It is a current belief that large fires and the cannonading during battles cause precipitation.

Singularly enough the belief that battles occasion rain is older than the invention of gunpowder. Thus we read in Plutarch: "It is a matter of current observation that extraordinary rains pretty generally fall after great battles;" and he explains it that either some divine power in this way cleanses the polluted earth or that moist and heavy vapors steam forth from the blood and thicken the air, and make the moisture fall.

It should also be borne in mind by those who believe in the effectiveness of cannonades in bringing on storms, that according to Arago ("Thunderstorms," pages 164–165) during the latter part of last century, and as late as 1810, it was a popular practice in the communities of southern France to fire off batteries, especially kept for the purpose, in order to *dispel* violent rain and hail storms, which were undesirable visitors of the region. Arago traced the history of this belief to a naval officer in that region, who had propagated the practice of navigators of that time of dispelling waterspouts and thunder

clouds by that means. Before this innovation the effect was sought by the ringing of church bells. Arago tried to disprove such an effect and to prove the opposite by showing that during the artillery practice at Vincennes, out of 662 days each preceding, following, and during the practice, there were cloudy 128, 146, and 158 days respectively. This seems to be a rather small percentage to establish the positive effect he claimed; however, it may prove the futility of the opposite belief.

Napoleon has been credited with making use of the experience that battles produce rain, in the disposal and manœuvering of his troops, and the belief in cannonade and rainfall as cause and effect has since become quite current.

The most elaborate effort to obtain evidence on this point is that of Mr. Edward Powers in his book, "War and the Weather, or the Artificial Production of Rain," published in 1871, when the extraordinarily wet seasons concomitant with the war movements in France brought the subject into prominence.

Although the writer himself, who took part in the campaign and well remembers the inclemency of the season, can not recall a single instance when engagements were followed by rain that would not have been anticipated from the general conditions of the atmosphere, yet he will not deny that the evidence collected by Mr. Powers from the Mexican war and that of the rebellion, with a few other additions, appears at first sight cumulative and overwhelming. In many cases, however, even the very imperfect records allow an explanation of the rainfall as due to natural conditions without effect of the cannonading, and it may well be asked whether as many, and even more, records could not be gathered of battles which were not followed by rain. Most of the evidence is drawn from recollections with which I find other recollections at variance, and since altogether general meteorological data for the period from which these records are drawn are lacking, the evidence after all falls considerably below the standard of positive proof. The negative proposition only is proved, that not all battles are unaccompanied by rain, as not all dreams fail of realization. In the accumulation of such evidence the danger is lest we indulge too readily in the "*post hoc ergo propter hoc*" argument. It would have to be shown that there were no well-understood natural reasons present for the occurrence of precipitation. In fact a few careful correspondents of Mr. Powers point out that such reasons often existed. The position taken by Maj. Gen. Thomas I. Wood, in his letter to the author, seems to be the proper one. He says:

Many battles have been followed by rain, while others have not. This fact would seem to indicate that it the atmospheric disturbances caused by the firing in battle have any effect in producing rain, the actual accomplishment of rain depends, in a general manner, if not chiefly, on the condition of the atmosphere. The condition of the atmosphere should, hence, be one of the chief factors to be observed in the experiments you propose.

The only actual experiment that has come to the writer's notice in which a cannonade seems to have been directly effective was reported a short time ago in La Nature and is vouched for by a M. Guillaume. A French artillery division moved out for a sham battle; when ready for action a dense mist arose, which obscured the entire valley so that one could not see 300 feet. One of the officers, recalling the asserted influence of cannonades, proposed to try the remedy; four mortars fired 1-pound charges, first eight shots in suc-

cession, then two salvos of four each, when suddenly the mist disappeared, clearing the valley for 3 miles, and a fine drizzling rain fell, which, as the cannonading of the sham battle continued, did not cease all day, sometimes falling in heavy showers. I have not been able to ascertain the authenticity of this report and the general weather conditions prevailing at the place and time.

Our present meteorological knowledge does not give much hope for success by this method of rain production. A method which appeared more reasonable, or at least one that seemed to be in agreement with our present theories of storm formation, was proposed by the author of these very theories.

The belief in fires and rain as cause and effect is also a very old one, but it was Espy who first, in 1839 (having shown that a column of air rising to a height where, owing to diminished pressure, it would expand, was by this expansion cooled, thereby condensing and eventually precipitating its vapor), proposed experiments "to see whether rain may be produced in time of drought, making a large body of air ascend in column by heating it."

Besides his general theories, which were accepted as most reasonable explanations of the formation of storms, he brought forward evidence to show that volcanic eruptions and large fires (he also refers to the cannonade of battles evidently as producing heat) were followed by rainfall.

The evidence is of the same kind as that brought to show the effect of cannonades. The negative cases, where conflagrations failed to produce rain would probably be found as numerous as the positive ones. In almost all those which allowed an analysis of atmospheric conditions, these were favorable to cloud formation, namely, a high dew-point and a calm and sultry air, which Espy admitted were needful conditions and which, at least the former, are rarely present in times of drought. The great fires of London and Chicago are cases in point. In forty-two large fires and two serious explosions, occurring in Australia, during twenty-one years, "there was not one instance in which rain has followed within forty-eight hours as an evident consequence of the fire."

It will again be interesting here to note that Volta, the great physicist, proposed to use fire for the very opposite effect, namely, to dispel thunderclouds.

The impracticability of this method was exposed by Mr. H. C. Russell, government astronomer at New South Wales, who showed that in order to increase by 60 per cent the rainfall at Sydney, where the average humidity is 73, and wind velocity 11 miles per hour, at least 9,000,000 tons of coal would have to be burnt daily, since it would be necessary to raise a column of air over a surface of at least 10 miles by 1,000 feet to a height of 1,800 feet; and while there may be found some flaws in his calculation, it gives an approximate idea of what forces are to be dealt with and of their enormity.

Mr. Russell, who was then (in 1884) antagonizing the idea of inducing the Australian Government to engage in experiments like those now proposed here, concludes:

> It would seem unreasonable to hope for the economical production of rain under ordinary circumstances, and our only chance would be to take advantage of a time when the atmosphere is in the condition called unstable equilibrium, or when a cold current overlies a warm one. If, under these conditions, we could set the warm current moving upwards and once flowing into the cold one, a considerable quantity of rain might fall; but this favorable condition seldom exists in nature.

Professor Henry, one of our most enlightened and unprejudiced physicists, expresses himself as follows in regard to Espy's propositions:

I have great respect for Mr. Espy's scientific character, notwithstanding his aberration in a practical point of view as to the economical production of rain. The fact has been abundantly proved by observation that a large fire sometimes produces* an overturn in the unstable equilibrium of the atmosphere and gives rise to the beginning of violent storms.

To understand how precipitation may possibly be effected by artificial means, it is necessary to know how it occurs in nature. First we must have a source of moisture, and then conditions which will cause the condensation and precipitation of that moisture.

Besides the moisture carried into the atmosphere by its direct evaporation from the soil and minor water surfaces in the locality under consideration, there is an amount, and in most cases probably the largest amount, brought by currents from such large water surfaces as the seas. It may be taken for granted that the evaporation from the great oceans furnishes the largest amount of the water of the atmosphere.

To conceive the conditions under which the air is likely to give up this water held in suspension, it is necessary to know first that air can hold suspended an amount of vapor proportioned only to its temperature. If the temperature be lowered by any means the vapor will be condensed, while an increase of temperature permits a further increase of vapor. In order, then, to produce condensation, it is necessary either to cool the air to or beyond the point (dew-point) where it can no longer hold the vapor, or to add to its moisture as much or more than it can hold at its present temperature.

The next thing to know is that the air, being heated by contact with the earth, which receives its warmth from the sun, is warmest near the ground and cooler farther away from its source of heat; and warm air being lighter than cold, it rises, being displaced by the cold air, which sinks and takes its place to be warmed and to rise, so that there is a constant circulation of air currents established. At the same time by evaporation moisture is added to the air in contact with the surface of the ground, and vapor being lighter than air the upward movement is thereby assisted.

The third factor of importance is that air in ascending cools, because by moving into regions of less pressure (the column of air compressing it being less as it ascends) it expands, and in doing so renders a certain amount of its heat latent, namely, the amount which is necessary to do the work of expanding, hence the sensible temperature of the air is reduced, and in consequence, as we have seen, its capacity to hold moisture, and hence it is brought nearer to condensation. The exact reverse is the case in descending air, namely, as it is compressed under the increasing amount of air above it some of its latent heat becomes sensible heat; it becomes warmer and capable of holding more water, and hence is less liable to condense its vapor. The general rain conditions of any locality depend upon its position with reference to the air currents coming from sources of moisture, and especially the elevations intervening.

The cooling of the upper air strata and the condensation of the moisture which they carry, mainly derived from the great sources of water, the seas, is assumed to take place by ascending air currents.

*Should perhaps read, "is accompanied by."

The ultimate causes of these ascending currents are stated by Prof. Cleveland Abbe in Appendix 15 of the Annual Report of the Chief Signal Officer for 1889, in which he also discusses in detail all the forces now known to be at work in storm formation, as follows:

(*a*) Very local heating of, and evaporation into, the lower stratum and resulting steep vertical currents or interchange of air, due to differences of buoyancy produced by the heat and the moisture, and which differences continue to exist in the ascending mass, relative to its surroundings, until the heat is lost by radiation and the moisture by precipitation.

(*b*) Very widespread differences of temperature, such as that between arctic and equatorial regions, plateaus and lowlands, oceans and continents, the dark half and the illuminated half of the earth, these produce a nearly horizontal flow of air underrunning and uplifting the lighter air.

(*c*) The advent of the horizontal flow into a region where the coefficient of horizontal resistance on the earth's surface is increased, such as the flow from the smooth ocean to the land surface, or from horizontal smooth prairie to hilly country.

(*d*) The forcible pushing up over hills and plateaus and mountain ridges of air that would have moved horizontally toward a region of low pressure were the ground horizontal. Such cases occur systematically when a region of low pressure advances toward a mountain range.

(*e*) An updraft from the lower stratum is caused when the air immediately above it becomes abnormally buoyant, either by the sudden formation of cloud, rain, and evolution of heat, or by the warming effect of the sun on the cloud.

(*f*) An important irregular movement takes place when the air passes over hilly countries, due to the fact that the horizontal current impinging against the side of a hill is by its inertia driven upwards; it soon descends again and strikes other hills, and thus any given isobaric or isostatic surface has an undulation similar to the standing waves in a shallow stream flowing over a rocky bed. The interference of these uprising downflowing currents with the ground and with each other causes a loss of horizontal velocity, a thickening of the depth of the horizontal flow, a slight increase of static pressure.

(*g*) The local heatings and evaporation mentioned in paragraph (*a*) are most active during sunshine and sensibly zero at night time. These produce in the daytime uprising and conflicting currents and an increase of pressure.

With the fact before us that the ascending current is cooled and thereby condenses its vapor, we explain the aridity of the interior basins and the plains. The Pacific Ocean is the source of moisture, which is carried landward by the west winds. As these strike the coast range and again the mountain ranges of the Sierra Nevada they are forced to ascend, expand, and cool, and drop part of their moisture. Descending on the other side, they arrive not only much drier; but by compression much warmer. Not finding any additional source of moisture to enrich themselves from, except the scant evaporation from the ground, they pass over the interior basin and are made to ascend again the Rocky Mountain range, and that several thousand feet higher than before. Again they are drained and again they descend as warm and dry winds; hence the low relative humidity, deficient rainfall, and high evaporative power of the winds in the plains. Incidentally, I point out again here how under these circumstances the forest cover on the eastern slopes of these mountain ranges is of so much greater importance than on the western slopes, as it is likely to aid in recuperating to some extent the moisture conditions of the descending current, while with the removal of the protecting soil-cover its drying effects would be aggravated.

The amount of atmospheric moisture, then, in these regions which are, I suppose, to be mainly benefited by artificial rain production, for the reasons stated is exceedingly scanty, their mean relative humidity being below 45° during the months of vegetation. In order to bring air in such conditions to condense its vapors there must be

either a considerable addition of moisture or a very considerable amount of cooling effected, for which artificial means seem entirely inadequate.

There occur, however, times when the cloud formation would indicate that a considerable amount of moisture is suspended near the point of condensation, yet no precipitation takes place, probably on account of a stable equilibrium of air masses over large areas. It is at such times that there is more hope for influencing condensation and the timely or local discharge of the clouds.

But, if our present philosophy of the causes that produce condensation is correct, it can hardly be conceived how explosions can produce the ascending current necessary to effect the cooling of the upper strata. It must not be overlooked that the effect is to be produced through heights of more than 1,000 to 2,000 feet, and the disturbance of the stable equilibrium must encompass a considerable air column. While in such cases the possibility of results from mechanical disturbances like explosions may not be doubted, the use of these means for practical purposes remains extremely doubtful in consequence of the amount of explosive material which it would be necessary to use in order to produce results. Neither the disruption and violent agitation of the air, nor the thermal changes, nor the smoke produced by ordinary explosions would appear, either singly or combined, of sufficient magnitude to change conditions, as we have only lately learned during the explosion of the Dupont Powder Works, when 100 tons of powder exploded in eight seconds without producing an effect upon weather conditions.

We are then brought to the conclusion that, unless other forces than these mechanical ones and other movements than these mass movements, play a rôle in rain production and can be originated or set in motion by human device, we may as well abandon the attempt.

To the meteorologist, who, with the opportunity of watching the daily weather maps, the path and progress of the great storm centers eternally moving around the earth, probably often without disintegration, like the eternal motion of the earth itself, is brought face to face with the great cosmic causes of storm formation, who knows that an area of not less than 400,000 to 500,000 square miles must be under the influence of barometric depression, to the amount of say half an inch before the storm discharges, the attempt to influence this grand natural phenomenon by the explosion of a few thousand pounds of powder or a fire of practicable dimensions appears indeed puerile.

Relying upon the working theories now accepted as explanatory of storm formation, he can calculate the omnipotent immensity of forces at work, against which limited human efforts seem utterly hopeless. This very year, almost as I am writing, Professor Hann, of Vienna, the highest living authority in meteorological science, has I believe definitely proved what has been long contended, that our storms are only partial phases of the general circulation of the air, and even the variation in terrestrial surface conditions, the heating and cooling of continents and seas, as well as the local influx of water vapor and its condensation, are only of secondary importance, while we had hitherto considered them the causes of storms, barometric differences, etc. He admits that they may strengthen or destroy the ascending or descending eddies and modify their paths and their rate of progress, but insists that they can not act as primary causes. Other meteorologists, with questionable show of good phi-

losophy, ascribe the storm-producing air currents to magnetic forces of the earth, and the eddies and storms as a result of a readjustment of these forces.

And yet, while we may admit that the great storm movements are due to cosmic causes, we must not overlook that within their path there are minor terrestrial influences, sometimes not of entirely uncontrollable magnitude, which seem to influence within certain limits the localization of storms and the temporal distribution. We claim this influence for instance for forest areas, water surfaces, etc.

All together the theories for storm formation, while perhaps sufficient to explain the general philosophy, do not seem capable of explaining satisfactorily the smaller modifications and side shows, as we may call the exhibition of local showers, thunderstorms, and squalls. Nor can it be said that the detail of the manner in which the vapor condenses and the rain drop is formed or in fact the forces active or conditions necessary in this condensation are fully known or understood. Who could, for instance, account for the fact that the dew-point may be at and above 100 without precipitation occurring? We know some seemingly necessary conditions, but we do not know all. For want of experimental knowledge meteorology seems to have lagged behind the times.

While the mass movements that are calculated to satisfy the existing theories of general storm formation may be necessary for such formation, is it altogether inconceivable or unphilosophical to think that other, molecular, forces may participate and in fact be a condition *sine qua non* in forming precipitation? Is it not also conceivable that, as in many chemical reactions it is only necessary to give the impetus to molecular motion to initiate the change, metabolism, which, being induced at some center of formation, spreads and assumes greater and greater proportions, similar processes may take place in the condensation of vapor from the air? If such were the case the expectation of at least a partial control by human agency might well be realized. Suggestions of this kind have been made before, not only by those who would suggest any forces to explain phenomena without understanding the possibilities of such forces to do the work, but by physicists upon the experimental basis.

Laboratory experiments by Mr. Aiton seem to indicate the presence of dust particles as an essential condition for rain production; and, although Professor Abbe "dismisses from consideration at present" the influence of atmospheric electricity in storm production, he does so only because we know too little about it and because an assumption of such influence does not seem to help the accepted theories of air movements as sole causes. Even so, he is compelled to admit that "actual measurements of electrical potential would seem to show that two masses of air in extreme conditions may attract or repel each other electrically to an extent sufficient to produce appreciable phenomena of motion even in comparison with the far more important motions produced by solar heat and terrestrial gravity."

That the air is generally negatively electric during rain storms was first established from over ten thousand observations by Herschel. Lord Rayleigh showed experimentlly that moderately electrified water drops tend to coalesce, but that strongly electrified drops repel one another, from which we may infer a real causal connection between rain and electrical manifestations; and after all, even though the ascensional current may be the primary cause for cloud formation, electric conditions may determine the precipitation,

We have hitherto been told that the electrical discharges during thunderstorms are the sequel and not the cause of the condensation; but this is by no means proved. Nor is the following explanation of any assumed effect, given by Professor Abbe, the only possible one:

> Even if we allow that the condensation of smaller cloud particles into large rain drops and their consequent fall to the ground depends upon the electrical discharge, yet this assumption if adopted will merely modify our mechanical views somewhat, as follows: The latent heat evolved in condensation must be considered as not wholly consumed in directly warming the air, but as partially employed in maintaining a state of electrical disturbance or tension, which latter comes to an end as soon as the flash or the silent discharge of electricity occurs. At this moment, therefore, on the one hand larger drops are formed and fall to the ground, and on the other hand the energy that had been potentially present in the electric phenomena now becomes heat and warms and expands the air. Thus the electric tension and its concluding flash have merely served to delay the communication to the air of the heat that was a few minutes before present in the vapor.

It was Sir William Thompson who first suggested that changes of weather might be foretold by the change from positive to negative electricity of the air or the reverse, and who devised the instruments for such observations in the electrometer and "water dropper." Unfortunately when, some few years ago, the U. S. Signal Service undertook some experiments in that line, under the direction of Prof. T. C. Mendenhall, this object of weather prediction was kept in the foreground, and the experiments, which form the basis of a voluminous report still unpublished, were only too soon abandoned because they did not yield readily results for the purpose in view. I am assured by the gentleman who was in charge of these investigations that, if carried on without this immediate object in view, they would undoubtedly have led to a better understanding of atmospheric conditions, and are worthy of further pursuit.

In conclusion I may refer to the observation that dust particles are found always charged with positive electricity, which may account for their office in rain production, and that experiments by Professor Trowbridge, of Harvard, on the effect of flames upon the electric conditions of the air would lend countenance to the belief in the effect of fires on rainfall, while the possible origination of electric currents as a result of friction in cannonades is suggested by Mr. Powers as an explanation of their assumed effect.

We may say, then, that at this stage of meteorological knowledge we are not justified in expecting any results from trials as proposed for the production of artificial rainfall, and that it were better to increase this knowledge first by simple laboratory investigations and experiments preliminary to experiments on a larger scale.

If explosions are to be tried at once then it would be necessary at least to take all possible precautions to ascertain the state of the atmosphere in all particulars before, during, and after the explosions, and to conduct and refer to the experiments rather as investigations into the effect of explosions upon the atmosphere than with the ultimate desired result in the foreground.

CONCLUSION.

The same recommendations which have been repeatedly made in my former reports as to the work to be pursued by the Division and as to the manner of advancing the forestry interests of the country

in general may be repeated, only with more emphasis than before, although with the increased appropriations and facilities provided this year, not only can certain lines of work, which the Division had tentatively laid out, be placed upon a desirable basis, but it will also be possible to devote more time and attention to the missionary work, which must needs still form part of our endeavor to change the forest policy of the United States.

B. E. FERNOW,
Chief of Division of Forestry.

Hon. J. M. RUSK,
Secretary.

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